GEOLOGIC ATLAS OF THE UNITED STATES

ANTHRACITE-CRESTED BUTTE FOLIO, COLORADO

1894

DESCRIPTION OF THE ELK MOUNTAINS.

GEOGRAPHIC RELATIONS.

The Elk mountains form a group of peaks which lie west of the continental divide in western-central Colorado. They extend about 45 miles from southeast to northwest and are 25 miles across, with their geographic center near the intersection of the 39th parallel north and the 107th meridian west. In this latitude the Rocky mountains proper consist of the Colorado, Mosquito, and Sawatch ranges, the last lying east of the Elk mountains.

The group is of equal average altitude with these ranges, having many peaks of 13,000 to 14,000 feet elevation. Exposed by their western position to the moisture-laden currents of the upper atmosphere—the return trade winds from the Pacific over the deserts of Arizona—these heights receive the first and most abundant precipitation of Colorado and are deeply scored by water-worn valleys and gorges. They are, moreover, largely made up of great masses of igneous rock which have better resisted the action of abrasion and erosion than the more yielding sedimentary beds. For these reasons they are characterized by bolder and more picturesque scenery and a more luxuriant growth of forest and verdure than any other portion of the Rocky mountains except the similarly situated San Juan mountains to the south.

The Elk mountains are drained through four main streams, whose valleys surround the group. Two of these, Roaring fork and Rock creek, flow northward into Grand river; whereas the other two, Taylor and Slate rivers, run southward into the Gunnison. The valleys of these four streams form the natural avenues of approach from the east and west valleys of the larger rivers. The development of coal mines at various points about the group and the discovery of silver deposits at Aspen led to the construction of railroads, which now make the region accessible from either end.

GENERAL GEOLOGY.

A reconnoissance of this group of mountains was made by the Hayden survey in 1873 and 1874, and the report for the latter year contains an admirable account of the prominent features of its structure, by W. H. Holmes, excellently illustrated by maps, cross-sections, and sketches. The work that has been done in this area by the members of the present survey, while finding many details and complexities of structure which had necessarily escaped the observation of the first explorers in this difficult and then almost unknown region, confirms, so far as it goes, the substantial accuracy of Mr. Holmes's description. This later examination has, however, been extended only over the southern and smaller portion of the group, and deductions drawn from such an incomplete study must necessarily be tentative and subject to future modification. The general facts of the geologic history of the group, as thus far determined, may, however, be stated.

The Paleozoic sea.—The Rocky mountains contain many areas of gneiss and granite, generally assigned to the Archean period, which are nuclei surrounded by younger strata. In the Elk mountains these most ancient gneisses are directly overlain by sediments of upper Cambrian age, so that there is no record of the geography of the region during the intervening Algonkian period and the early Cambrian. The history commences late in the Cambrian period with the deposition of sediments beneath a sea in which the Archean rocks formed islands. In the Elk mountain area there does not appear to have been any such island or land mass standing above the water level at that time, although it is probable that what is now Treasury mountain, near the center of the area, projected above the general level of the ocean floor as a sunken reef. The nearest land masses were the Sawatch island, to the east of the Elk mountains, and one of unknown dimensions to the south, occupying in part what is now the Gunnison valley.

From the Sawatch island and from other land areas detrital matter was washed into the sea, forming sediment. The detrital matter consisted of clay, quartz sand, and other mineral particles of the crystalline rocks, which were sorted and distributed by waves and currents. The first sediments deposited in this ocean were almost exclusively siliceous; that is, they consisted of rolled grains of quartz, which is the hardest of the minerals that constitute the crystalline rocks. Hence these deposits resulted from the slow and long continued action of waves breaking on bluffs or beaches, abrading and triturating the softer minerals, such as mica and feldspar, which were thus so finely comminuted as to be carried away in suspension in the ocean waters and deposited farther from the land. But this action was not indefinitely continued, for the conditions changed. The materials, which at first were coarse, were followed by others which were finer, and finally consisted almost exclusively of mud and silt. The Cambrian and lower Silurian rocks are mostly sandstone or quartzite. They are coarse at the base and finer grained and more calcareous toward the top. The rocks of the succeeding upper Silurian period are to a great extent limestone and shale. There were apparently no Devonian deposits, and consequently the process of sedimentation was interrupted; yet the strata of the lower Carboniferous resemble those of the upper Silurian, indicating that during both these periods the water was deep and quiet and the land was low.

The apparent interruption of sedimentation during the Devonian period, which has also been observed in other parts of the Rocky mountains, was not accompanied by any disturbance of the strata; consequently if the failure of deposition be attributed to elevation of the area above the sea, the uplift must have been general, causing the waters to recede; but it may be that the distribution of land and sea was not materially changed, and that the lack of sediment during the Devonian was due to a low level extending over the land. The local occurrence of arenaceous beds of variable thickness between the Silurian and Carboniferous strata is consistent with either hypothesis.

Carboniferous movement.—The gradual rise or subsidence of a portion of the earth's surface, by which land areas are, in the one case, extended at the expense of the sea, or by which the sea, in the other case, invades the land, may occur without marked disturbance of the rocks in their positions relative to each other or to the earth's surface. But in the earth's mass there are other movements, usually in a horizontal direction, which may tilt previously flat strata; and still other strains may develop which, opening fissures, may permit the extrusion of molten rock. These eruptions of molten matter may be confined to subterranean depths, or they may reach the surface, where they become apparent in some form of volcanic activity. The three forms of terrestrial disturbance—the slow vertical movement, the more energetic but still gradual horizontal motion, and the violent eruption of igneous rocks—may occur separately or in combination.

The sequence of sediments, which began in the Cambrian period and was recommenced after the Devonian intermission, closed with the deposition of lower Carboniferous strata. It ended with an important orographic, or mountain-making movement, the first of which there is distinct evidence in this region, which involved both vertical and horizontal motion, apparently without igneous activity. Important changes in the distribution of land and water areas were brought about, and the Cambrian, Silurian, and lower Carboniferous strata were uplifted and folded. Land rose from the sea south of this region, and possibly in other adjoining areas. The Cement mountain region was affected by this uplift, but it probably was not entirely raised above ocean level.

Erosion attacked vigorously the uplifted areas, which yielded a large amount of generally coarse material. The strata of the later Carboniferous are correspondingly thick, as compared with those of the preceding sequence of sediments. They accumulated rapidly in shallow and troubled waters. The first beds deposited were of black bituminous shale, at times carrying enough carbonaceous matter to form thin beds of impure coal. Being in some places completely overlapped and concealed by the succeeding strata, these shales evidently were formed along a sinking coast. Above the shale beds, in which occur occasional, thin beds of limestone, are alternating strata of sandstone, shale, and limestone, which grade into the characteristic beds of the higher series. These are alternations of sandstones and coarse conglomerates of reddish or chocolate color, remarkable for the great number of limestone pebbles which they contain. Where these beds have been subjected to metamorphic action, as is not infrequently the case, they lose their reddish color and assume a greenish tinge from the presence of the mineral epidote, a product of the alteration of the iron-bearing minerals previously contained in the beds. Sometimes the limestone pebbles are changed to white marble by the same action.

The prevalence of limestone pebbles in the conglomerate is significant of climatic and topographic conditions and of the nature of the formations exposed to erosion. In a wet climate, where vegetation flourishes, limestone is dissolved, and erosion then yields lime in solution and residual red clays. Pebbles are rarely formed. But in a relatively dry climate, where heat, cold, and frost shatter rocks more rapidly than solvent waters dissolve them, limestone yields fragments, which are rounded in being carried by streams. The mechanical action of waves beating on an abrupt coast may also produce limestone pebbles. Since limestone is softer than the siliceous rocks of which conglomerates are usually formed, it is probable that limestone pebbles are rapidly abraded and reduced to silt. Their occurrence indicates, therefore, that the fragments have not been carried far from their place of origin. Since no limestone beds are known to have been formed in this region prior to the Silurian period, it follows that these pebbles must be fragments washed down from land areas where Silurian or lower Carboniferous rocks were exposed. Hence the submarine deposits formed in the previous cycle of sedimentation must have been lifted up into land areas on the borders of this region before the limestone conglomerates accumulated. This is confirmed by the fact that casts of fossil shells of Carboniferous age have been found in some of the limestone pebbles.

The maximum thickness of these upper Carboniferous beds has been estimated at 4,500 feet. Above them in adjacent regions are found beds of brick red sandstone, which are also conglomeratic at times and generally show ripple marks. They were, therefore, deposited in shallow waters along a coast line. This brick red sandstone was probably formed in the earlier part of the Juratrias period, though no decisive evidence from fossils has yet been obtained in favor of this view, for the physical character of these, as well as of the upper Carboniferous rocks, shows that they were deposited under conditions unfavorable to the preservation of remains of organic life. In the absence of fossil evidence it is not possible to determine the exact line of division between the Carboniferous beds and those of the next succeeding period, especially since the general characters of the rocks of the two periods are quite similar and the changes that are recognized are very gradual. Nevertheless it is quite evident that the red sandstone is wanting in many of the rock sections exposed in the region, and it may be assumed that it was partially carried away by erosion in consequence of an uplift which succeeded the epoch of its deposition. In regions west of the Elk mountains the red sandstone is overlain by sandstone, shale, and limestone, containing marine fossils of the European Jurassic age. As these beds are not found at all in this district and are also wanting in other parts of the Rocky mountains, it is reasonable to assume that the Elk mountain area was above ocean throughout the latter part of the Juratrias period.

Pre-Cretaceous movement.—After the deposition of the above-mentioned sediments another important orographic movement took place, which resulted in a certain amount of folding of the previously deposited beds. Portions of the Carboniferous and succeeding beds were raised above water and subjected to erosion. Whether there was any exhibition of volcanic energy and accompanying intrusion of igneous rocks at this time has not yet been determined. After a lapse of time there followed a gradual subsidence of the land areas, commencing another cycle of sedimentation, which continued to the close of the Cretaceous period.

The first deposit in this series of sediments was of sandstone, followed by shales and occasional limestone beds whose fossil remains indicate that they were deposited in fresh or lacustrine waters. Hence the ocean waters must have been for a time shut out from this as from other portions of the Rocky mountains. From what is thus far known of the life of this epoch, it appears to correspond with that of the latter part of the European Jurassic and has been included in the Juratrias. Everywhere in intimate association with these fresh water sandstones and shales, and lying conformably upon them, are similar sandstones which are often conglomeratic at the base, and of exceptionally hard texture, so that they always form prominent outcrops. These strata carry abundant plant remains, and further east fossils of marine origin. They are the Dakota sandstone or quartzite, the lowest beds of the Cretaceous period in the Rocky mountains, though in other parts of the West, notably in Texas, Mexico, and in British Columbia, a considerable thickness of earlier Cretaceous beds is found below this horizon. Hence, although the fresh-water sandstones of the Juratrias and the marine Dakota sandstones are so closely associated that they were regarded by the early geologists as a single formation, it is evident that a considerable lapse of time must have occurred between the existence of the fresh-water lake and the invasion of the sea over this region.

The character of the sediments deposited during the Cretaceous period indicates the usual cycle of sedimentation in an ocean which was first deepening and then growing gradually shallower. The sandy beds of the Dakota were shallow-water deposits in a slowly advancing ocean, which sorted out and carried away the fine mud. In the succeeding Montana and Colorado epochs the sediments from the land consisted predominantly of clays. Shales, with some limestone beds, were formed, the waters being probably deeper and more quiet. Toward the close of the Colorado epoch sand again became abundant in the sediments. During the succeeding Laramie epoch the deposits consisted chiefly of sandstone with extensive coal beds, indicating that the sea repeatedly swept over the area, spreading beach sands, and as often retreated, affording opportunity for luxuriant growth of vegetation. The character of the animal life of the Laramie shows, moreover, that the waters in which its beds were deposited had become brackish or fresh; and, as all beds deposited in the Rocky mountain region since that time are of fresh-water origin, it is evident that, during the Laramie period, oceanic waters were shut out from the region to return no more. The Laramie was a most important epoch in the history of the Elk mountain region. The formation of its many and valuable beds of coal laid a substantial foundation for future industrial development, and at its close was inaugurated a great and energetic igneous action, which blocked out the larger features of the present mountain structure and was directly or indirectly the cause of the great concentration of metallic deposits in the region.

Post-Laramie movement.—Although in other parts of the Rocky mountains there are evidences of volcanic energy in the intrusion of igneous rocks before or during the Laramie epoch, in the Elk mountain region none of the numerous masses of eruptive rock observed can with certainty be assigned to an earlier date than the post-Laramie. Immediately above the Laramie in this region, however, is found a considerable thickness of beds constituting the so-called Ohio and Ruby formations. The latter is composed in large part of eruptive material, which proves that there must have been an eruption of igneous rock previous to their deposition. The age of these beds has, however, not yet been definitely determined, as they contain no organic remains. They are later than the Laramie, with which they are apparently con-

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formable in inclination, and their position indicates that they were probably deposited before the earliest Eocene beds yet recognized in the Rocky mountains. They are cut through by dikes of igneous rock, and being themselves composed of eruptive material they show that the movement and the eruptive action which accompanied it were not a single manifestation of telluric energy, but a succession of such manifestations. The earth movements, moreover, which intensely compressed the sedimentary beds and produced folds and faults, were continued in a modified degree through Eocene times, being especially energetic at the close of the Bridger epoch (Eocene). These successive disturbances raised the mass of the Elk mountains. In the present structure of the region, exposed along the valleys and gorges carved out by subsequent erosion, the effects of the original post-Laramie movement are confused with those of the later disturbances. It has not been possible to distinguish between them. In the following description of the growth of the mountains, therefore, the results of the several movements will be considered as a whole.

The area principally affected by the dynamic movements is a longitudinal zone some 40 miles in length, extending in a northwest direction from Italian peak to Sopris mountain. At the inception of the movement the Juratrias and Cretaceous beds probably covered the whole area of the Elk mountain group, though during the general elevation, which must have commenced in Laramie times, this region may have early become an island, so that the Laramie sediments were deposited only on its western flanks.

The movement must at first have been catastrophic in its nature, probably the sudden relief of an intense and long accumulating strain. Great, irregular fractures were produced and filled by a molten magma that has since consolidated into granular diorite. Whether any of this molten mass ever reached the surface cannot now be determined, for thousands of feet of rock above the present surface have since been worn away; but the crystalline structure of the diorites that are now exposed shows that they must have cooled slowly under the pressure of a great mass. The diorite exposures now form three mountain groups: that of Whiterock and Star peaks, that of Snowmass and Capitol peaks, and that of Sopris peak. Between the two former masses are Pyramid and Maroon peaks, the highest points in the group, which are formed of nearly horizontal Carboniferous beds that have escaped erosion. The outlines of these great diorite bodies, which are several miles in diameter, are very irregular, and they inclose many and enormous fragments of the sedimentary beds through which they were intruded. The Whiterock and Star peak mass, on the Crested Butte sheet, is the only one of these shown on the maps now published.

The sedimentary beds within and on the borders of this disturbed area are crumpled into folds and broken both by normal and overthrust faults, showing the effects of an intense compression which may be easily conceived to have been caused by the intrusion of such enormous masses of extraneous matter between the unyielding buttress of the Sawatch (Archean) area and the great expanse of undisturbed sediments of the Plateau region. Hence on the western flanks these sedimentary beds are sharply folded, forming reversed folds and a few overthrusts. In the higher portions of the mountains they show a tendency to buckle over toward the west, while on the eastern portion of the area, between it and the Sawatch range, normal faulting is predominant. The prevailing movement on the fault planes, especially in the neighborhood of Aspen, is such as to suggest a general sinking of the Elk mountain district relative to the Sawatch mass. This local subsidence was perhaps a consequence of the extravasation of so much material in a molten form from beneath the area.

It is probable that the intrusion of the laccolitic masses in the relatively undisturbed area to the south and west of the diorite peaks, such as Gothic mountain, Crested Butte, and Mount Wheatstone, occurred after a lapse of time whose duration can not now be determined, though it was geologically very short. The molten rock welled up through fissures and spread out between the strata, not sensibly disturbing the beds below the laccolites, but causing those above to arch over them. The structure of these intruded rock masses shows that they, too, must have cooled at some distance from the surface, but it is possible that upper portions of them, as of the diorite eruptions, may have been exposed to erosion, contributing to the formation of the Ruby beds. However, this may have been, eruptive action did not cease until long after these beds had been laid down, as is attested by the numerous intrusive masses and dikes, some of highly crystalline structure, which cut through them. The greater hardness of the igneous rock has maintained the heights of the Ruby range above the level of the areas occupied by softer sedimentary rocks on either side.

A small mass of rhyolite is found on the Crested Butte sheet, and another exists just east of the limits of the sheet, both of them occurring in close proximity to underlying Archean rocks. The date of their eruption can only be proximately determined as later than that of the more crystalline diorites and porphyrites; that is, as of Eocene or later times. To this indefinite age must for the present be assigned also the formation of the West Elk breccia, represented in the southern portion of the Anthracite sheet. This area is part of an immense extent of rudely bedded material in the Gunnison valley, which has not yet been thoroughly studied.

Since at the time of the consolidation of the present mountain-making bodies of diorite and porphyrite great thicknesses of sedimentary rocks still rested above them, the relative height of the mountain area must have been far greater than it now is. But the actual elevation above sea level, which cannot be definitely determined, may have been less considerable, for it is probable that the effect of the later earth movements has been to increase the uplifts begun during the post-Laramie movement, rather than to develop new ones. Thus there has probably been a slow elevation of the mountain areas, which has partly compensated for the wearing down by erosion.

Erosion has acted on the region continuously since the post-Laramie movement. During the Eocene period it was probably more active than at the present day, and the material removed from this and other parts of the Rocky mountains was carried out into the interior sea that then occupied the Plateau region of the Colorado basin, forming the beds of the Wasatch and Green River (Eocene) formations, which still extend over a large portion of the surface. The younger and less resistant beds were probably most vigorously attacked. Their general ablation resulted in blocking out the larger mountain forms by the carving of the broader valleys, like those of the Gunnison and Grand. The formation of the complicated network of minor valleys which constitute the existing drainage system occurred much later, and the final shaping of these gulches and of the present rugged mountain forms has been in large measure accomplished since the Glacial period. Indication of a stage in this process of mountain sculpture is afforded on Mount Wilkinson, a basalt-capped table, which lies between the valleys of Slate and Ohio creeks (Crested Butte sheet) and which rises more than 2,500 feet above the bottom of these valleys. Beneath this basalt sheet, and resting on the eroded surface of the Montana and Laramie (Cretaceous) strata, is a low ridge of loose gravel composed of rounded pebbles of diorite and other rocks, which was apparently once either a moraine or part of an ancient river bed. The basalt flow probably changed the course of the original stream and diverted it to a position in which it carved one of the modern valleys.

Most of the streams now head in characteristically shaped glacial amphitheaters, which are locally known as basins, while morainal deposits abound in all the valleys, but as no special study has been made of the moraines they have not been indicated on the map.

The differing topographic forms of the basins and of the valleys which lead out from them afford a means of estimating the amount of erosion since glacial times. Being at altitudes where their surface is covered with snow or ice for two-thirds of the year, the basins suffer but little erosion by running water, and retain the U-shaped form of the glacial valley. Their broad, flat bottoms descend into the V-shaped valley below, which has been carved out by running water since glacial times. Thus the difference of level in the descent through the V-valley affords a minimum measurement of the depth of modern erosion, which amounts in places to 1,000 feet, varying with the volume of water and the relative resistance afforded to erosive action by the differing character of the rocks in which the valley has been carved. A simple inspection of the topography as shown on the map—for instance, at Peeler basin and O-Be-Joyful gulch—will enable the eye trained in the reading of topographic forms to appreciate the difference in result of the two kinds of erosion, though it is of course much more readily apparent on the ground.

MINERAL RESOURCES.

SOUTHERN ELK MOUNTAINS.

The principal mineral resources of this region are building stones, brick and fire clays, limestones, bituminous and anthracite coals, bog iron ores, and precious metal deposits, including under the latter head ores carrying not only gold and silver but also iron, lead, zinc, antimony, and copper in subordinate values. Of these only the coal beds and precious metal deposits have thus far been exploited for export.

STRATIFIED ROCKS AND ORES.

Building stones.—The most readily available building stone is the Dakota sandstone, which is very durable, capable of supporting great weights, and easily quarried on account of the regularity of its bedding planes. It outcrops along the borders of the lower Slate river valley in immediate proximity to the railroad, and has been quarried to a certain extent in the Gunnison valley, south of the limits of the area now mapped. Some of the red sandstones of the upper Carboniferous and almost all the eruptive rocks, as well as the Archean granites, would afford good building stones were they so situated as to be easily transported. Extensive deposits of valuable marbles, resulting from the metamorphism of the Silurian limestones, occur on upper Yule creek opposite the head of Slate river, only a few miles beyond the northern limit of the Anthracite sheet. It was because of the extent of the exposures of Silurian limestones at this point that the local name of Yule limestone was given to this formation. Here are found not only remarkably pure white marbles, but also a great variety of colored marbles of the most varied hues.

Clays.—The middle Cretaceous strata furnish excellent clays, but they are much better suited for brick making after they have been washed down and redeposited by streams. Such alluvial deposits may be found in the flood plains of the larger valleys, generally beneath the surface gravels, wherever the waters at their higher stage in these valleys were quiet enough to permit the clay to settle.

Lenticular beds of fire clays, such as are worked at Golden, are generally found within the sandstone beds of the Dakota formation. Although no beds have yet been opened along the outcrops of the Dakota sandstone represented on the Crested Butte sheet, the black clay lines which indicate their presence are readily recognizable, and intelligent prospecting would doubtless discover them. Beds of impure fire clay also occur above the coal seams in the Laramie sandstones.

Limestones sufficiently pure to be used as fluxes or for lime burning may be looked for in the Yule and Leadville formations, along the valley of Cement creek from the bend downwards. At two points in this valley are considerable deposits of travertine or calcareous tufa, formed by the waters of hot springs issuing from these limestones. The Niobrara limestone, which is remarkably persistent and pure on the eastern flanks of the Rocky mountains, seems to be less developed in this region, but if there were sufficient demand for it, good lime could probably be obtained from the outcrops of this formation along the west side of lower Slate river valley and on the east side of the valley of East river, especially near the mouth of Cascade creek.

Bog iron.—Beds of bog iron occur at various points in the region as the result of the decomposition and leaching of underground deposits of sulphurets by thermal waters, but none have proved to be of economic value. The largest deposits of this iron ore occur in Redwell basin, on the north side of Scarp ridge, and on the southern flanks of this ridge, in the valley of Coal creek, about opposite Redwell basin.

Coal.—The outcrops of the sandstone beds at the base of the Laramie formation, which contain the workable coal seams of this region, are indicated on the economic maps by a dark shade of olive green. By the aid of these indications and of those given on the structure sheet, the areas in which coal seams may possibly be found and the probable depth of the coal below the surface are readily determinable. Whether a given seam of coal is of quality or thickness to be profitably worked can be determined only by actual exploration to a considerable distance from the outcrop. Detailed accounts of the coal-bearing rocks will be found in the subsequent description by Mr. Eldridge. The coals of this region are light bituminous coals, good coking coals, semi-anthracite, and anthracite of excellent quality. It is a well known fact that coals are altered where a mass of igneous rock is intruded into contact with them or near them, the heat of the molten material being effective to a considerable though varying distance. At many points in this region this phenomenon is observed, the same coal seam passing from anthracite in the immediate vicinity of the eruptive rock, through coking coal, into unaltered dry bituminous coal, as distance from the igneous mass increases.

The largest area of anthracite coal, of which the excellent 6-foot seam on Anthracite mesa is a remnant, is, however, so situated that its alteration to anthracite cannot be attributed to the heat of an intrusion. But there is abundant evidence, both in the general structure of the area and within the coal seam itself, that there has been intense compression of the beds, producing a certain amount of differential motion, part of which has found expression in small faults. It seems to be a legitimate deduction from these conditions that the energy of the force of compression was in part transformed into heat, which was sufficient to produce the anthracitization. Whatever may have been its origin, this area of anthracite is the largest yet known outside of the Pennsylvania fields, which are also devoid of eruptive rocks and have suffered intense compression. The areas of anthracite demonstrably due to contact metamorphism alone, on the other hand, have thus far proved to be too limited to be of much economic importance.

PRECIOUS METALS.

The precious metal deposits of the Southern Elk mountains have proved to be of greater geological than economic importance. From a geological standpoint they present extremely interesting and instructive illustrations of the structure and manner of formation of fissure vein deposits. They also yield fine specimens of many of the rich and rarer metallic minerals. From an economic standpoint they have proved extremely disappointing, for in spite of favorable geologic conditions, of promising surface indications, and of extensive prospecting, their aggregate product, in the decade that has elapsed since the region has been actively worked, has been comparatively small. It might be said, in explanation of this fact, that most of the rich deposits thus far opened have been found at such altitudes and in such inaccessible positions as to render their exploitation very difficult and expensive. Another and perhaps more plausible reason may be found in the structural conditions of the region, the ore deposits being distributed through a great number of small fissures, instead of occurring in great ones like the Comstock, Ontario, or Granite Mountain lodes, or in easily soluble beds, like the limestones of Leadville and Aspen.

Mineralogic character.—The mineralogic character of the ore deposits is very varied. The common sulphurets (galena, zincblende, and pyrite) are of almost universal occurrence, but as a rule contain very little silver or gold. Arsenopyrite is of common occurrence in the Ruby district, in association with the rich silver minerals. The more common rich silver minerals are ruby silver, both pyrargyrite and proustite, and gray copper or tetrahedrite. Of local occurrence are the rarer minerals freieslebenite and warrenite (sulphantimonites of lead), smaltite, erythrite, and nickeliferous lœllingite. Native silver is of common occurrence, resulting from the decomposition of the rich silver minerals. Native copper is found also in small amounts. As gangue minerals, quartz and calcite are most common. Barite and siderite are found and also, though rarely, fluorite.

Gold does not occur to any considerable extent in the ores, but was found in the placers of Washington gulch, which were worked as early as 1860, but have long since been abandoned. The gold is said to have been highly argentiferous, and worth only about $12 per ounce.

Distribution of the ore deposits.—The following general facts are noticed with regard to the distribution of the ore deposits in this region. They are most frequent and more commonly rich in the neighborhood of bodies of igneous rocks, whose intrusion has been accompanied or followed by extensive fracturing or shattering of the rocks, and in such regions the ores occur more frequently near the contact, or in the adjoining sedimentary beds, than within the mass of eruptive rock. Thus the great laccolitic bodies, like Gothic mountain and Crested butte, which have apparently been formed without much fracturing or shattering of the strata, have comparatively few ore deposits in their vicinity. Ore deposits are also more frequent in the siliceous than in the argillaceous beds. But little ore has been found in the unaltered clays of the Colorado Cretaceous strata (the Benton and Niobrara formations), whereas the greatest developments have been discovered in the sandstones and siliceous shales of the formations above and below them. The limestones within the area represented on the two accompanying maps have been but little explored.

Structural conditions.—Those portions of the area in which ore deposits have been most abundantly found are broken up by an intricate and irregular network of small faults, most of which are of too limited extent to be represented on the maps. The ore deposits are invariably found upon the planes of some of these faults, generally of such as have a vertical displacement of less than a hundred feet and a longitudinal extent which is too small to constitute an important feature in the general geologic structure of the region. These faults cut across both sedimentary and eruptive rocks, hence the dynamic movement which produced the original fractures must have occurred since the deposition of the latest Cretaceous strata. The most typical fault fissures are found in the Ruby beds around Irwin. The sedimentary beds affected by them are unusually plastic and, being of comparatively recent formation, have not suffered much induration. Hence the compression and consequent displacement have left remarkably distinct evidence of their action in dividing the country rock into very thin and well defined sheets by a great number of small, parallel planes on which the movement of displacement is distributed, in striations on the walls, and in attrition breccia or broken fragments of country rock in the spaces between the walls. The ore and gangue fill the interstitial spaces in the breccia and between the sheets of country rock, sometimes partially replacing the fragments or sheets. Thus instead of thick veins of white quartz more or less impregnated with metallic minerals (the general conception of a fissure vein) the vein deposits of this region are more frequently a series of thin, parallel sheets of mixed country rock and metallic minerals, with somewhat indefinite lateral limits of mineralization. The fault fissures that are most easily recognized on the surface have not, as a rule, proved most productive, although in the productive fissures, when sufficiently opened by underground workings, proofs of compression and displacement, in striations, breccia, and sheeting of the country rock, are always easily seen. The fact that the fissures consist not of a single fracture but of a series of parallel fractures, generally closely spaced, has often misled the miner, especially where one of these parallel fissures has been filled by a seam of quartz, which, being harder than the adjoining country rock, forms a well-defined wall, beyond which he is apt to think it useless to look for ore, whereas, in reality, it may be found on one or the other side of such a wall in different parts of the same mine. The direction or strike of the mineralized fault fissures is generally included in the northeast-southwest or northwest-southeast quadrants, but some trend north-south or east-west. Their dip is in most cases nearly vertical. No persistent relation of richness or abundance of mineral to direction of fissure could be observed either for the whole region or for special parts of it. As a general rule each smaller area or mining district has two principal systems of nearly parallel fissures which make angles of 40° to 60° with each other, but the directions of these principal fissure systems vary from one part of the region to another, and are evidently dependent on local conditions.

ANTHRACITE SHEET.

In the area represented on the Anthracite sheet the richest and most abundant ore deposits have been found on the flanks of the Ruby range; at its southern end around the larger eruptive mass of Ruby and Owen peaks, and about Augusta and Richmond mountains at its northern. They have been developed to a less extent in the Laramie sandstone of Scarp ridge, which is traversed in every direction by thin sheets and dikes of eruptive rock, and also in the Montana formation, near the eruptive bodies of Cinnamon and Baldy mountains, in the northeast portion of the area.

Irwin district.—In the Irwin or Ruby mining district, on the east flanks of Ruby peak, the principal mines are the Bullion King and the Forest Queen mines, which in 1887 had both been explored about 300 feet vertically and to a somewhat greater extent horizontally, and had yielded a considerable amount of rich but refractory ore. The Bullion King fissure, near the east base of the great dike that runs south from Ruby peak, has a strike of north 40° east and dips 65° northwest. The enclosing rocks are beds of rather soft shale and sandstone of the Ruby formation. The main ore values are found in rich sulphides, arsenides, and antimonides of silver, which are associated with blende, pyrite, and a little galena. The mineralized zone, consisting of thin sheets and breccia of more or less altered country rock, cemented by quartz and metallic minerals, occupies a width of four to six feet, but parallel fissures, sometimes mineralized, are found from 20 to 50 feet on either side of this zone.

At the eastern end of the town of Irwin, following a ravine in a northeast direction, the Forest Queen deposit occurs in a fault fissure which is nearly vertical or inclined northwest with a slight hade. This is also a compound fracture, but as the enclosing rocks consist of hard porphyrite, sandstone, and conglomerate, there are fewer parallel fault planes. The porphyrite was apparently an intrusive sheet following the bedding, but the compound fracturing often gives it the appearance of a dike within the mineralized zone. The ore is largely arsenopyrite and rich silver minerals, cementing breccia fragments which are included in the plane now of one and again of another fault fissure. The complications of structure combined with the hardness of the porphyry have made the mine a difficult one to work.

In the basin at the east base of Ruby peak a great many openings have been made on fissures running east and west, having the same general character of vein material, the ore constituting the cementing material of attrition breccia, in a zone of sheeted country rock. The striations on the walls of these east and west fissures have an inclination of 45° eastward, showing that the movement of displacement in a horizontal direction has been about equal to the vertical movement. Those fissures which occur within the porphyrite body south and east of Irwin have similar characteristics of brecciation and striation, but the faulting is generally distributed on fewer fracture planes.

In the Laramie sandstones along O-Be-Joyful gulch are many mineralized fissures, which generally carry low grade sulphurets, with little or no rich silver ore. In Redwell basin, at the east end of Scarp ridge, a little native copper is found in the coal-bearing sandstones. The red well, from which the basin receives its name, is a pool of iron-bearing water fed by a spring issuing from the Laramie strata at the upper part of the basin. The limonite deposited by these waters has formed a thick layer in the bottom of the basin, and in one place has covered the outcrop of a vein carrying galena and pyrite. When this was first uncovered it was thought by some that the latter minerals were also of recent formation. In the basins at the head of O-Be-Joyful gulch are many so-called spar veins, where the fissure has been filled by lamellar calcspar, with curved faces and pearly lustre, forming sheets one to two feet thick and generally barren of metallic minerals.

Augusta mountain district.—The head of Poverty gulch is a centre of mineralization second in importance only to the region around Irwin. The sedimentary rocks found here are the sandstones at the base of the Laramie and those at the top of the Montana formation. They surround a great intrusive mass of diorite, and are cut through in every direction by dikes and sheets of that rock, and by a few dikes of white porphyry. The whole region is shattered by an immense number of small faults, crossing both the sedimentary and the igneous rocks, which are frequently so metamorphosed that it is difficult to determine from the hand specimen to which class they belong.

The principal mine is the Augusta, situated near the summit of Augusta mountain. The upper tunnel, only 400 feet in length, pierces the mountain from side to side. Its ore house in Poverty gulch, nearly 3,000 feet below, is connected with the mine by a wire tramway over one and a quarter miles in length. The fissure has a direction of north 75° east at its eastern end, and south 60° west at its western end. It cuts both the diorite and the sedimentary rocks, and the striations on the walls show that the movement was extremely varied in direction. The ore, which consists of the ordinary sulphurets with gray copper and ruby silver cementing the breccia and replacing the basic constituents of the eruptive rock, is found in a width of 1 to 6 feet. It had been followed at the time of visit to a depth of 165 feet below the tunnel level, the ore shoot having a length of about 200 feet. There appears to be less sheeting of the country rock than in the Irwin veins, which would be explained by the greater hardness of the country rock.

Other veins have been opened to a greater or less extent on the slopes of Augusta mountain, in Baxter basin, and on the steep northern slopes of Richmond mountain. They all possess the characteristics of fault fissures, mentioned above. A few are entirely within the igneous rocks, but the greater number cut sedimentary beds as well. On the east side of the crest of the range they have generally a northeast or north direction, and on the west side a direction between northwest and north. Of the veins on the western slope the most prominent are the Saint Elmo, Domingo, and Richmond mines. The former, nearest the crest of the range, is in diorite; the Domingo vein crosses diorite sheets and Laramie sandstones; while the Richmond is in the upper part of the Montana formation. These mines were quite extensively worked in the early part of the decade and produced some very rich ore, but have long been abandoned, probably because of the inaccessibility of their situation. Besides the sulphurets, they contained gray copper, rich silver minerals, and a new sulphantimonite of lead, warrenite, locally known as "mineral wool." From the mines in Baxter basin, another sulphantimonite of lead, treieslebenite, which is also locally called "mineral wool," has been obtained in a similar association of minerals. A small percentage of gold was also found.

Cinnamon and Baldy mountain district.—In the highly altered Montana beds on the borders of the diorite body, forming the valley known as Paradise flat, several fissure veins have been opened, carrying sulphurets and several large sheets of calcspar, but no considerable quantity of the richer silver minerals has been discovered. The general direction of the veins is nearly north and south. In the black (Fort Pierre) shales of Slate river valley, opposite Cinnamon mountain, several fault fissures running north 20°–30° east have been opened, some of which are parallel to or adjoin narrow dikes of igneous rock. Only low grade sulphurets seem to have been found.

On the south slopes of Mount Baldy and in the head of Washington gulch considerable prospecting has been done on fissures in the Montana shales, near bodies of igneous rock. Their principal direction is northwest. The Painter Boy mine, near the deserted town of Elkton, at one time produced considerable rich ore from a fissure in the shales, which is said to have been cut off by a horizontal sheet of porphyrite. The material on the dump, which is a mixed breccia of shale and porphyrite, shows that the fracture must have crossed the porphyrite sheet, and the supposed cutting off was probably an impoverishment of the vein within this rock.

It is interesting to note that the gold-bearing placers of Washington gulch, which have yielded considerable highly argentiferous gold, must have been largely formed by the erosion of the Baldy and Cinnamon mountain masses, in whose veins, as far as known, no gold-bearing minerals have been found. This fact is in so far a disproof of the generally received idea that placer gold is mainly derived from the detritus of veins. Nuggets containing vein quartz must undoubtedly have been derived from this source, but it is probable that a very large proportion of the fine gold in placers was originally finely disseminated throughout the rock masses and did not necessarily proceed from veins of economic importance.

CRESTED BUTTE SHEET.

Whiterock mountain district.—The principal mineral developments in the area represented on this map have been found in the vicinity of the great Whiterock diorite mass. They occur, as a rule, either at the contact of enclosed or adjoining sedimentary rocks or in fissures cutting across both sedimentary and eruptive rocks. They are remarkable rather for the richness and rarity of the mineral species found in them than for the extent or continuity of their ore bodies.

The best opportunity for studying this type of deposit was afforded by the Sylvanite mine, which is situated on the steep northern slopes of the gorge of Copper creek, at an altitude of about 12,000 feet. The openings are just beyond the northern limits of the map, at the point indicated by the crossed hammers. In spite of its almost inaccessible position it has been quite extensively worked and has yielded a considerable amount of remarkably rich ore, consisting largely of native and ruby silver. The deposits occur in parallel, en echelon fissures, which run northeast and southwest and, standing nearly vertically, cut across both diorite and metamorphosed Carboniferous strata. They are just on the outer limits of the great diorite body, the mountain in which they occur being cut through in every direction by dikes and intrusive masses of diorite, and the sedimentary beds being so metamorphosed as to be in places scarcely distinguishable from the eruptive rock. In 1887 these fissures had been explored over 300 feet horizontally and about 500 feet vertically. They cut through both diorite and sedimentary beds and are fracture planes on which there has been a slight displacement. The vein material, a few feet thick, is in part extraordinarily rich in native silver, ruby silver, and argentite. The bulk of the vein material is quartz, with some calcspar and pyrite, which fills the interstices and to some extent replaces fragments of crushed country rock.

In Queen basin, on the southwest side of Whiterock mountain, several mines were opened, in early days, in the steeply upturned slates of the lower part of the Maroon formation. The valuable mineral in these deposits seems to have been mainly gray copper.

On the southeast face of Whiterock and at the northwest base of Teocalli, mines have been opened whose ores occur in masses of altered sedimentary rock entirely enclosed by the diorite. These are interesting as containing, besides the usual rich silver minerals, some carrying nickel and cobalt, among which lœllingite and smaltite have been recognized.

Ore has been found in the Carboniferous rocks at Avery peak, near its summit. Considerable work has also been done in Virginia basin on deposits occurring on fracture planes crossing the Dakota and Gunnison sandstones, with a northeast strike and nearly vertical dip, which are said to have yielded rich ores.

Fissure deposits have also been opened in the diorite and upper Carboniferous strata near Pearl pass and Carbonate hill. The limestones of the Carboniferous and Silurian within the area of the Crested Butte sheet have thus far shown but little mineral development, but cannot be considered as thoroughly prospected. The ores here follow bedding planes and irregular fracture and joint planes; they are mostly galena and pyrite and their decomposition products. The principal openings are at the very head of Taylor river, and near the bend of Cement creek, in limestones that have been assigned to the Weber formation. Considerable deposits have been opened in the Paleozoic limestones just east of the limits of the map. Of the age of the different ore deposits mentioned above but little can be said definitely except that most of them have been formed since the diorite intrusion. They may be older than those occurring in the area of the Anthracite sheet, but there is no direct evidence of difference in age, though the diorite was evidently of earlier intrusion than the Ruby range eruptives.

SAMUEL FRANKLIN EMMONS,
Geologist in Charge.

July, 1894.

DESCRIPTION OF THE IGNEOUS FORMATIONS.

ANTHRACITE SHEET.

The igneous rocks of the Anthracite district present three strongly contrasting modes of occurrence. First, and most prominent, are the great laccolites and closely related intrusive sheets; second, a remarkable system of dikes; and third, a great series of volcanic breccias, tuffs, and semi-conglomerates. Both laccolites and dikes penetrate the uppermost Cretaceous strata, and are certainly of Tertiary age.

The chief rock types represented are diorite, porphyritic diorite, porphyrite, and andesite. Quartz-porphyry and granite-porphyry are found among the dikes of the Ruby range, but could not be specially indicated upon the map. The petrographical character, occurrence, and distribution of the principal rocks will be considered in detail.

DIORITE.

Description.—The diorite of Cinnamon mountain is a medium grained quartz-mica-diorite containing a little green hornblende and a large amount of orthoclase. It is a strongly feldspathic rock, and where the dark constituents have been decomposed and the iron leached out there remains a very white mass. Plagioclase occurs abundantly in rude crystals, the largest grains in the rock, while orthoclase, quartz, biotite, and a little hornblende appear in irregular grains of smaller and more variable size. Magnetite, titanite, apatite, and zircon are present as usual in such rocks.

This type is closely allied to the diorite of Whiterock mountain, Italian peak, and other large masses of the Elk mountains. The diorites of Augusta mountain and Mount Owen will be described in treating of the dike system of the Ruby range.

Occurrence.—The Cinnamon mountain diorite penetrates the Montana Cretaceous strata in the form of a large stock, with nearly vertical contacts wherever seen. There are many small offshoots into the surrounding shales, not shown upon the map. The shales of Mount Baldy and Cinnamon mountain are much hardened and metamorphosed, while the diorite disintegrates readily on weathering. Hence Paradise basin is excavated in this diorite stock, while the adjacent mountains are made up of Cretaceous shales.

PORPHYRITE.

Description.—Under the general term porphyrite are here included by far the greater number of the igneous rocks of the district. They are all intrusive, holocrystalline, porphyritic rocks, which are chemically and mineralogically equivalents of granular diorites. On account of considerable differences in chemical composition and in conditions of occurrence these rocks present a variety too great to be described in detail in this place, but the prominent characteristics of the group will be given.

The porphyrites are all characterized by many crystals of a soda-lime feldspar (plagioclase) and a holocrystalline and generally granular groundmass. In by far the larger number of cases phenocrysts (i. e., distinct crystals) of biotite and quartz are associated with the plagioclase, while hornblende appears in some modifications, and then quartz is generally rare or wanting. In those rocks especially rich in quartz and biotite, and particularly if the mass is large, there are crystals of orthoclase, usually much larger than those of any other constituent, some reaching a length of three or even four inches.

The groundmass is of very variable composition and structure. In the large masses, such as Mount Axtell, Mount Carbon, etc., where the rocks are rich in quartz and orthoclase, the groundmass is an even grained aggregate of these two minerals, with slight amounts of other constituents. With this composition the grain varies from that of the coarser varieties, where the particles can be seen with the naked eye, to one so dense that the microscope fails to distinguish between quartz and feldspar. In rocks poor in quartz, here occurring mainly in small sheets, the groundmass is less evenly granular, and is darkened by mica or hornblende or obscured by their decomposition products.

By increasing coarseness of grain in the groundmass the porphyrite may grade into diorite. Thus the mass of Mount Marcellina has acquired a structure so nearly granular that the rock has been separately indicated upon the map, though strictly belonging to the porphyrite series. Upon the Hayden map all of these larger laccolite bodies except the Storm ridge mass were called "porphyritic trachyte." The latter body was not separated from the breccia surrounding it.

Occurrence.—The porphyrites of this district occur in crosscutting dikes or in bodies intruded more or less distinctly parallel to the stratification planes of the sedimentary rocks. The latter masses vary in size from sheets a few feet in thickness and with considerable lateral extent, to huge lenses, called laccolites, more than two thousand feet thick. The regularity of many of the sheets is quite surprising in view of the shaly nature of the strata into which they are intruded. Crosscutting from one horizon to another and a splitting of one sheet into two are common features.

The relationship between the thin sheets and the large laccolites is clearly demonstrated in the mass of Mount Axtell. This large body of quartz-mica-porphyrite, with large crystals of orthoclase, is found to be injected into the sedimentary series at a horizon just above the base of the Ruby beds. There is a thin stratum of the latter formation between the Laramie and the base of the porphyrite mass as seen at several localities about Mount Axtell: at its eastern base; on the western border, south from Ohio pass; and on the north. From the contact east of Mount Axtell to the summit, more than one thousand feet of the porphyrite is shown, and its thickness at this point was once still greater. Toward the north, in the region east of Irwin, this mass thins out and passes as a sheet between the strata of the Ruby beds. On the northern cliff of Scarp ridge and in the basins on the southern slope the sheet appears as a very regular body ten to thirty feet in thickness and faulted with the enclosing strata. In passing into a thin sheet the rock loses its large orthoclase crystals, though they do not entirely disappear until the thinnest parts of the body are reached. Increasing density and fineness of grain also characterize the passage to the thin sheet.

The character of the larger porphyrite masses is also indicated by the small laccolites which are revealed by the canyons of Cliff and Anthracite creeks. At the tops of the canyon walls the strata are seen resting on the porphyrite and curving down at the ends of the exposures. On the eastern, northern, and western borders of the Mount Beckwith laccolite the Ruby beds dip away from the eruptive mass. On the north of the Anthracite range porphyrite is seen disappearing conformably beneath the Laramie strata, and on the west the beds are steeply upturned against it.

Where so many large bodies are injected into shaly and loosely consolidated strata, at short distances from each other, it is manifestly impossible for the beds to assume the regular position with respect to each eruptive mass which they might occupy in regard to the typical laccolite. The rocks differ sufficiently to indicate that the bodies were not contemporaneous, and a later injection must undoubtedly have irregular contacts with the beds on the side toward a neighboring laccolite. The huge talus slopes covering contacts on the more precipitous faces of the laccolitic bodies make observations impossible on the line of some of these apparent ruptures.

Storm ridge is a mass of fine grained porphyrite, seldom exhibiting large orthoclase crystals. It is for the most part surrounded by the volcanic breccias of the West Elk range. The outline of this mass is but approximately correct, and its former relationship to enclosing strata can not now be determined, owing to erosion and to the great talus slopes which conceal contacts.

Gothic mountain is a laccolite remnant resting on dark shales which pass under it almost horizontally.

Distribution.—The porphyrites occur in all parts of the Anthracite district, as shown by the map, and they are also abundant in the adjacent regions of the West Elk mountains on the west, north, and east. In Ragged mountain, a few miles north of Mount Marcellina, is a huge laccolite of coarse grained porphyrite, and here the strata run high up on the outlying spurs, resting plainly on the laccolite core, and contain thick intrusive sheets.

The geological distribution of these intrusive sheets in this area is much more extensive than is represented on the map, but the various Cretaceous horizons are those at which the sheets are most likely to be found.

Age.—From the direct evidence of the masses of Mount Axtell, Mount Beckwith, and Mount Marcellina, it is clear that these great laccolites are more recent than the Ruby beds, which constitute the highest known Cretaceous formation. They are therefore clearly of Tertiary age. But the formation of great laccolites is supposed to require the presence of several thousand feet of strata above the horizon at which they are injected. The coarsely crystalline structure of these masses also implies that there must have been a thick covering of sedimentary beds. These considerations make it necessary to assume that the Wasatch and perhaps other Eocene formations extended over this area at the time of the laccolitic eruptions.

PORPHYRITIC DIORITE.

Description.—The rock of the laccolitic mass of Mount Marcellina belongs to the porphyrite series of eruptions, but it has developed a structure which it is desirable to emphasize by a name indicating the intermediate place it occupies. Macroscopically the rock appears to have a fine grained granular structure, but microscopical examination shows that there is really a groundmass of so coarse a texture that its grains nearly equal the phenocrysts of plagioclase and biotite in size. Quartz is confined to the groundmass and occurs in very uniform crystals of imperfect shape. No large orthoclase crystals were observed in this mass. The rock was termed "eruptive granite" upon the Hayden map.

Occurrence.—The mass of Mount Marcellina bears irregular relationship to the sedimentary rocks, which could not be traced out in detail. In Prospect point and on the north side of Anthracite canyon the Laramie beds dip away from the eruptive mass. On the northwest Mr. Eldridge found a strip of Montana shales between the eruptive and the Laramie, while on the west bank of Anthracite canyon, at the southeast corner of the mountain, the Ruby beds seem to abut against the eruptive. Huge talus slopes cover the base of the steep southern face of the mountain.

THE DIKE ROCKS OF THE RUBY RANGE.

Occurrence.—The Ruby range is due to a remarkable system of dikes which have hardened the strata penetrated, and partially protected them from erosion. This dike system stands in marked contrast to the more regular porphyrite intrusions which have been described, and is of somewhat more recent date. The dikes cut the sheets in all observed cases where they meet.

The main features of this dike system are shown by the map, but the number of dikes is much greater than could be represented. There are two irregular channels, one at Mount Owen and one between Augusta and Richmond mountains, connected by several large dikes; while from both centers extend a large number of dikes with a general trend somewhat east of north to west of south. Many of these dikes are more than fifty feet wide and some exceed one hundred feet, and a few have been traced continuously for several miles.

Certain of the dikes form very conspicuous features of the landscape. Thus the large one extending southward from Ruby peak stands out as a wall whose vertical sides are more than one hundred feet high in some places and whose crest is very jagged. Several of the dikes on the western slope of the range form sharp and prominent ridges, while the floor of Democrat basin is ribbed by many dikes. They are naturally very noticeable when cutting the soft Montana shale or the purplish Ruby beds, but where the shales are hardened and iron-stained, as in Mineral point, it is often difficult to trace them.

Description.—This dike system represents a series of eruptions whose products are closely related to each other in a manner of much interest to the petrologist. This is especially true of the rocks found in the channel south of Augusta mountain, for the way in which they gradually pass from one variety into another affords valuable evidence as to the phenomena of the eruption of magmas in such a channel, and as to the origin of rock facies. The changes in rock structure and composition within this mass are far too complicated for exhibition on the map.

The northern end of the Augusta mountain mass and a border zone of variable width extending southward along both contacts are composed of a very fine grained dark diorite, rich in biotite, hornblende, and pale augite, the latter two varying greatly in development. This fine grained diorite sends out a few short narrow dikes into the surrounding shales. It is traversed in many places by a network of narrow veins of quartz and pink orthoclase, and as these widen biotite appears sparingly. The diorite border zone is also cut by many dikes of porphyritic rocks, some of which extend for more than a mile into the adjoining country. The most prominent of these are quartz-mica-porphyrites with large orthoclase crystals.

Passing from the dark diorite of the contact zone toward the center of the eruptive mass the rock grows coarser grained and lighter colored and becomes a quartz-diorite, or, through the abundance of orthoclase, a granite. The darker constituents are the same as in the border facies except that biotite is relatively more prominent as a rule. By a development of large pink orthoclase crystals the rock becomes a granite-porphyry or diorite-porphyry. The transition from the fine grained to the coarse rock is sometimes quite sudden, though never a sharp line.

Tracing the dikes inward from the dark diorite zone the rock is found to become more granular and to grade into the coarse grained rock of the center, and the dike boundaries disappear. So both the border zone of the mass and the dikes which cut it pass by transitions into the same rock. These transitions were not followed out for all dikes, but none of those observed to cut the dark diorite could be identified in the inner part of the large mass. The relationships are clearest on the eastern border, between the two little lakes shown upon the map.

These relationships are interpreted to mean that this mass represents a channel through which several eruptions took place. The dark diorite represents the first magma, but before the whole had crystallized a somewhat different magma was injected and dikes of this material cut through the first rock. The gradation from one rock to another may be supposed to take place on the zone of incomplete crystallization of the earlier magma. The process was apparently repeated several times in the history of this channel. The detailed relations in support of such a view cannot be described in this place.

The mass of Mount Owen does not present the same transitions as the larger one, but diorite and porphyrite are both found there in connection with dikes which reach out north and south.

The dike rocks of the system vary considerably in composition and in details of structure, but they form a connected series. The majority of the large dikes are quartz-mica-porphyrites with large orthoclase crystals, some of them very similar to the laccolite rocks that have been described, but the orthoclase phenocrysts usually diminish in number and disappear toward the ends of the longer dikes.

A number of dikes are like these first mentioned, without the orthoclase crystals. Others have a smaller amount of quartz, and hornblende appears more prominently. Many of the smaller dikes are free from quartz in the form of phenocrysts and do not contain much in the groundmass. In this way there is a transition to porphyrites free from quartz, with a groundmass containing much plagioclase. Some of the smaller dikes are very fine grained dark rocks, rich in hornblende.

Contact zones of denser, darker material are present in some dikes and wanting in others.

In the vicinity of the two main centers of eruption there are a few granular diorite dikes of limited extent.

A beautiful white quartz-porphyry free from dark silicates is seen in dikes on the north face of Cascade mountain, in Mineral point, on the ridge above the Richmond and Domingo mines, and in an irregular intrusive sheet at the head of Slate river. This rock is cut by the porphyrite dikes. It was impracticable to represent these dikes on the map by a special color.

Age.—The distinct manner of occurrence of the Ruby range dikes and the fact that they cut the intrusive sheets of similar rocks indicates that the eruption is later than that of the laccolitic masses. Yet the similarity of magmas shows that they are probably to be referred to the same general eruptive period. It has been shown that the structure and occurrence of the laccolites proves them to be of Tertiary age, and nearly the same arguments may be applied to the dike rocks. They cut the Ruby formation, at the summit of the Cretaceous, but the number of dikes and their tendency to radiate from centers may indicate that a portion of the Tertiary covering above the laccolites had been removed at the time of the later eruption.

THE WEST ELK BRECCIA.

Occurrence and distribution.—In the southwestern corner of the Anthracite district appears the northern end of a great volcanic breccia which forms the West Elk mountains, and, as shown by the Hayden map, extends southward to the Gunnison river. In the West Elk mountains and outlying ridges, some of which extend into the Anthracite district, this volcanic material causes very wild and rugged mountain shapes, and isolated remains often bear fantastic resemblances to towers, castles, or cathedral spires. One of the most striking of these, "The Castle," stands on a rampart ridge between the forks of Castle creek, just south of the map line.

The bedded arrangement of the material as seen in cliff faces is very marked, but it is largely due to an alternation of coarse breccia with finer ash or tuff, and in the places observed is to be compared with the stratification common in products of volcanic vents, or produced by surface agencies, rather than with that of sedimentation. The location of the vent or vents from which this material was ejected is unknown, but it must be to the south or southwest of the district.

Within the district the massive breccia is seen at the head of Castle creek, on Swampy pass, and above it on the cliff-like face of the Anthracite range. At various places on Pass and Castle creeks are remnants of dark breccia, but many other exposures are of crumbling tuff and soft arenaceous material carrying some small eruptive fragments. The growth of timber and the debris covering slopes near Storm ridge and the Anthracite range conceal so much of the formation that the actual relationships to the Cretaceous have not been accurately worked out. It may be that the lower part of what is mapped as breccia may be more properly considered as a sedimentary formation. The observations made do not permit a distinction between such material and the breccia.

Rocks of the breccia.—In the ridges south of Storm ridge the breccias are best seen. Here they form loosely consolidated banks alternating with finer grained ash or tuff beds, containing some coarse fragments. None of the breccias seen are very massive. The fragments are prevailingly dark, fresh looking andesitic lavas of various textures. Microscopical examination of the fragments collected shows that hornblende-andesite predominates. Augite-andesite is also abundant. No quartzose varieties were seen, and no basalt. The series is overlain by rhyolitic lavas near the Gunnison, as ascertained by Dr. Peale during the Hayden survey.

CRESTED BUTTE SHEET.

Igneous rocks occur within the area of the Crested Butte sheet in small dikes; in large, irregular, intrusive masses; in intrusive sheets and laccolites; and in surface lava flows. They cut stratified rocks of all periods from Cambrian to Cretaceous, but none of the important masses is definitely known to be older than the Eocene. The important facts bearing upon this question will be given in connection with the discussion of the types.

Five rock types are distinguished upon the map, viz., granite, diorite, porphyrite, rhyolite, and basalt. These will be described, and some details of their petrographic character, occurrence, and distribution will be given.

GRANITE.

Description.—The granite here referred to is distinct from the types of the Archean complex. It is a medium grained, dark gray rock, whose essential constituents are pinkish orthoclase, white plagioclase, quartz, and biotite. Hornblende appears in the finer grained and darker colored contact zones. In composition this granite is near the boundary line between granite and quartz-diorite, for the two feldspars are nearly equal in amount. Quartz is somewhat less abundant than in normal granite, and the rock is to be considered as closely related to the adjacent diorite mass of Italian mountain. The rock is somewhat decomposed; the feldspars are dull, and biotite has been largely replaced by chlorite, giving the mass a greenish tinge. This mass was called "porphyritic trachyte" upon the Hayden map.

Occurrence.—The only mass of this granite known at present cuts the lower Paleozoic rocks in the southern part of Italian mountain, on the eastern border of the district. It forms the south peak of Italian mountain and extends southeasterly for some distance. On the western slope of the main peak the granite comes in contact with diorite, and, although the relationship of the two bodies is much obscured by debris, the presence of small dikes of diorite in the granite indicates that the latter is the older rock, although they doubtless belong to the same general period of eruption.

There is some metamorphism of the strata about the granite, but as it is most pronounced near the diorite mass it seems probable that the greater part of this alteration is to be attributed to agencies active at the time of the later eruption.

DIORITE.

Description.—The great irregular mass of diorite extending from Taylor peak along the Sawtooth range to Whiterock mountain, and thence across the northern border of the district, is typical of several large masses in the Elk mountains. It is fine grained, light gray in color, and very uniform in appearance over large areas. In general it is a quartz-mica-hornblende-diorite, but quartz practically disappears in certain places, while augite becomes an important constituent. In the average rock plagioclase strongly predominates over orthoclase, and biotite over hornblende. By a local increase in the amount of orthoclase, granitic facies (or modifications) are produced. Magnetite, titanite, apatite, and zircon are accessory constituents.

The structure is often typically granular, all the principal constituents being developed in irregular grains, but the plagioclase is frequently found in crystals. A porphyritic structure is very seldom found, the contact zones being merely finer grained than the average mass. The rock is often quite fresh, but is locally bleached.

In Italian mountain is a diorite mass closely related to that above described. It has the same constituents, and the quartz-mica-hornblende type prevails, though there are facies caused by variations in the amounts of quartz, orthoclase, and hornblende and the local appearance of augite. Another modification common here contains orthoclase partly developed in large porphyritical crystals (phenocrysts) making the rock a diorite-porphyry. Contact zones of this mass are apt to be rich in hornblende.

Both diorite masses, but especially that of Italian mountain, contain small veins of pegmatite, and thin seams in which amphibole, pyroxene, epidote, titanite, quartz, feldspar, and sometimes other minerals are deposited. Upon the Hayden map both of these rocks were called granite.

Occurrence.—The larger diorite mass occurs in intimate relationship to the great Elk mountain fold-fault. That this magma ascended through a break or channel whose walls were remarkably irregular is proved both by the form of the mass represented upon the map, and still more clearly by the great number of included fragments of the sedimentary rocks which have been torn loose from the adjacent walls. Some of these masses are a hundred yards or more in length, and sixteen of them are represented on the map. They are generally quite irregular in form, but their length is most commonly parallel to the stratification.

A pronounced metamorphism of the sedimentary beds surrounding or included in the diorite is a characteristic feature. This usually takes the form of a production of silicates of the bases formerly existing in oxide or carbonate compounds. The iron oxide of the red sandstones is combined to form epidote, and the limestone of each pebble of the Maroon conglomerate is changed into pure white, crystalline marble, while all the impurities may be concentrated in a single crystal of red garnet. Pyroxene and amphibole are common in the parts richer in iron. Vesuvianite, garnet, and scapolite are abundant in many places.

This metamorphism is most pronounced about the diorite mass of Italian mountain. In the wedge-like arm between the diorite and granite masses the impure lower Carboniferous limestones and shales have been completely transformed into a coarsely crystalline aggregate of vesuvianite, garnet, pyroxene, scapolite, epidote, and a number of less important species. The summit of Italian mountain is of this metamorphosed material. Analysis of several of these minerals shows that fluorine and chlorine were both active mineralizing agents in this period of metamorphism. Some of the minerals are found in very fine crystals, especially the vesuvianite.

Deposition of hematite iron ore has taken place in limestones at several points near the diorite, and both the diorite itself and the strata of the Maroon formation are in some cases impregnated with bright scales of hematite. None of the known iron deposits is of economic importance.

At the Luona, Horace Porter, and American Eagle prospects, in West Brush creek, are ores of cobalt and nickel in the form of smaltite, erythrite, and lœllingite, in included masses in the diorite.

PORPHYRITE.

Description.—The rocks here called porphyrite are distinctly porphyritic rocks, exhibiting many white plagioclase crystals, with quartz, biotite, and occasionally hornblende, and, in most cases, very large glassy crystals of orthoclase, often two or three inches in diameter. These prominent crystals (phenocrysts) are imbedded in a gray, granular groundmass, which the microscope shows to consist of quartz and two feldspars. The usual microscopic accessory constituents—magnetite, apatite, and zircon—are present.

The large masses of Mount Wheatstone, Crested butte, Gothic mountain, and the oval mass between the latter two mountains, consist of a grayish rock characterized by large and perfectly formed orthoclase phenocrysts. The size of these crystals makes them appear the most important constituent of the rock, but they are of varying abundance and are actually subordinate to the smaller but much more numerous plagioclase crystals. In obtaining hand specimens of the rock, 3 by 4 inches in size, it is not always easy to show more than one of the orthoclase phenocrysts.

The rocks of these masses vary somewhat in composition, and the rock of Crested butte seems to be the extreme in one direction. It is richer in silica and alkalies than any other one yet analyzed (silica, 65.71 per cent.; potash, 3.95 per cent.; soda, 5.00 per cent.) and is correspondingly rich in orthoclase, feldspars, and quartz. As the two feldspars are nearly equal in amount this rock might be called a quartz-porphyry, but it is considered better to class it with the other members of the series to which it belongs.

In the small dikes northwest of Crested butte and in the sheet below the large mass of Gothic mountain the porphyrite has a denser groundmass and the phenocrysts are smaller, but orthoclase is also developed here in relatively large crystals. The darker color of these smaller bodies is partly due to a finer grain and partly to chlorite and other products of decomposition which are disseminated through the mass.

The small dikes at the southwestern base of Crested butte are very fine grained, dark porphyrites, in which the orthoclase crystals are entirely suppressed and the other phenocrysts are much smaller. These bodies are like the contact zone of the main porphyrite body of the mountain above.

A somewhat different porphyrite is that of the sheet below the Niobrara Cretaceous, east of Gothic. It is a light gray, very fine grained porphyritic rock, with plagioclase, quartz, and biotite phenocrysts, all smaller than in the variety described, and does not exhibit any large orthoclases. It is probable that this body is more closely related to the diorite in origin than to the main porphyrite series.

Occurrence.—The numerous porphyrite bodies of the West Elk mountains occur in dikes and in intrusive sheets of varying dimensions, from those a few feet in thickness up to laccolites two or three thousand feet thick. These bodies occur at all geologic horizons from the Carboniferous to the post-Laramie of the Ruby beds.

In the Crested Butte area the large porphyrite masses of Crested butte, Gothic mountain, and Mount Wheatstone are laccolites, from which the soft shaly strata that once arched over them have been entirely eroded, and the great uniform masses of porphyrite carved into rugged mountains. At several places on each of these mountains contacts of the porphyrite and the strata beneath are plainly shown. These contacts are either approximately horizontal or dip slightly under the mass.

Points at which these relationships can be clearly seen are situated as follows: On the southern slope of Crested butte, above the little dikes shown on the map; on the eastern face of Gothic mountain, above the intrusive sheet; on Mount Wheatstone, at its southern extremity, and in the large gulch on its northern slope. On Crested butte a decided bench runs around the mountain just below the contact line.

The true character of these great rock masses is shown within the area of this atlas sheet by the smaller mass of the same rock occurring on the ridge between Gothic mountain and Crested butte. This is a smaller laccolite, and a remnant of the strata, resting on the eruptive rock and dipping at an angle of about 30° northwesterly, may be seen at the point nearest Gothic mountain. In the adjoining district of the Anthracite sheet are six large porphyrite masses, whose relations to the strata enclosing them are sometimes roughly indicated, but in Ragged mountain, lying north of the Anthracite sheet, is a huge laccolite in the Laramie formation, with strata resting upon it, as shown on the northern, eastern, and southern slopes.

The character of the large masses is also clearly shown by many bodies intermediate in thickness between the thin sheets and the massive laccolites.

RHYOLITE.

Description.—The rhyolite of Round mountain is a light gray, very fine grained, porphyritic rock. The most noticeable macroscopic constituent is biotite in small black leaves, but close examination shows many minute crystals of feldspar and quartz lying in a dense groundmass, which the microscope proves to be made up of quartz and feldspar, in a very fine grained aggregate. Plagioclase appears to be much subordinate to orthoclase, and chemical analysis confirms this conclusion. The groundmass exhibits a fluidal structure in some places, but seems to be holocrystalline.

On weathering this rhyolite breaks into thin sherds whose surfaces are usually iron-stained, and which ring like metal when struck. Owing to this surface weathering, solid rock outcrops are not common, notwithstanding the steep slopes.

Another rhyolite which may be mentioned here occurs in East mountain, on the ridge at the head of Deadman's gulch, just beyond the eastern border of the district. This mass has a fine grained holocrystalline center with smoky-quartz phenocrysts, and about it concentric zones becoming more and more glassy, passing through a perlite modification to an almost pumiceous outer zone. Certain zones contain the radiate crystallizations called spherulites and beautiful cavities with concentric shells, known as lithophysæ.

Occurrence.—The rhyolite mass of Round mountain is a stock-like body cutting up across several formations and sending off an arm northward, which seems in places nearly conformable to the adjacent strata, but in other places cuts irregularly across them. The contacts of the main mass are seldom visible, being covered by debris and vegetation.

From the structure of the rock it is to be inferred that it consolidated somewhat nearer the

surface than the porphyrites, and that it therefore belongs to a considerably later period, after erosion had removed much of the sedimentary beds. This conclusion is supported by the occurrence of rhyolite at East mountain, for, while the latter rock is clearly intrusive, its glassy zone and structure show that at the time of its consolidation there could have been but little of the Carboniferous beds above that part of the rhyolite mass now seen.

BASALT.

Description.—The capping sheet of Mount Wilkinson consists of several thin flows of a typical black basaltic lava. These show scoriaceous and vesicular outer zones and dense, dark gray or black rock within. The rock is usually very fresh, showing microscopic crystals of plagioclase, augite, olivine, and magnetite, in a more or less distinctly glassy base of brown color.

Occurrence.—The thickness of the basaltic capping now remaining varies from fifty to two hundred feet. Apparently the flows of Mount Wilkinson were once continuous with those of the flat-topped mesa a few miles to the south. The basalt rests upon an eroded surface of Laramie strata. Between different flows there is commonly some reddish volcanic ash, and below the first flow, at the northern point of the mountain, is a remnant of a basaltic tuff filled with bombs, or rounded ejected fragments. This formation is twenty feet thick and indicates the existence of a true volcanic vent at no great distance. Its location is not known.

This basalt is evidently the most recent eruptive of the district. Under it, at two points on the western slope, are beds of bowlders resembling moraines, and there is no known reason to object to the assignment of this eruption to the post-Glacial epoch.

WHITMAN CROSS,
Geologist.

DESCRIPTION OF THE SEDIMENTARY FORMATIONS.

STRATIGRAPHY.

ARCHEAN.

In the northeast and southeast corners of the district mapped there are small areas of granite and crystalline schists which have been exposed by the erosion of the overlying sedimentary beds. They consist mainly of granite and granite-gneiss, with local developments of gneiss and schists. The granites are generally gray in color and of medium grain, reddish and very coarse grained varieties occurring locally. They are usually rich in biotite, but contain also hornblende and muscovite. The quartzose mica-schists are sometimes fibrolitic.

CAMBRIAN STRATA.

Sawatch quartzite.—This formation, so named because of its persistent occurrence around the flanks of the Sawatch range, is the lowest sedimentary series in the region and is of upper Cambrian age. It is extremely variable in thickness, and is separable into a lower and an upper division, each of which forms prominent cliffs.

The lower division, which is from 50 to 200 feet thick, is a white quartzite with a persistent conglomerate of pure white quartz at the base. The upper division, which has a maximum thickness of 150 feet, is a red, ferruginous, and somewhat calcareous sandstone, consisting chiefly of quartz and feldspar, with a small amount of mica. A green, glauconitic mineral occurs in both divisions, but more abundantly in the upper. In the latter a few fossils of the Potsdam type were found. This division is apparently wanting at the head of Taylor creek, is 130 feet thick in Deadmans gulch, and 160 feet thick on lower Cement creek. The lower division, on the other hand, has a thickness of 50 feet at Taylor creek, 200 feet at Deadmans gulch, and 80 feet on lower Cement creek.

SILURIAN STRATA.

Yule limestone.—The Yule limestone is so named because of its fine development at the head of Yule creek. The aggregate thickness of the formation in the area of the Crested Butte sheet is from 350 to 450 feet. It consists of a lower division of quartzite, a middle division of limestone, and an upper division mainly of variegated shaly beds. The lower quartzite, 75 to 100 feet thick, is generally white, sometimes spotted by iron oxide, often calcareous, and contains indistinct fossil remains. The middle division, 250 to 280 feet thick, consists of limestones, often very thin bedded, which are frequently siliceous, especially at the base, and contain grayish white cherts. Their color is generally gray with pink or purple cloudings, turning to brown on weathered surfaces. On Yule creek they are altered to marbles of white, green, yellow, and other colors. They contain characteristic fossils, among which may be mentioned the fish scales abundantly found at this horizon near Canyon. The upper division, 60 to 90 feet thick, consists mainly of green, yellow, red, and white shales, with more or less arenaceous or calcareous layers, the latter passing into thin limestones. The persistence of its general lithologic character renders this horizon easily recognizable. The best localities for studying the Cambrian and Silurian strata, as well as the lower Carboniferous beds, are along the slopes of the lower valley of Cement creek, below the bend, and on the eastern slopes of Cement mountain.

CARBONIFEROUS STRATA.

Leadville limestone.—This formation is so called because it is the chief mineral-bearing horizon of the Leadville mining district in Colorado. It is also the ore-carrier in the Aspen and several other important districts. Its fossil remains are of sub-Carboniferous types. Its thickness varies from 400 to 525 feet, and it consists principally of beds of limestone from 5 to 30 feet thick, sometimes separated by bands of quartzite or calcareous shale. At the top of the formation is a massive, bluish black bed, 75 to 150 feet thick, known to miners as the "Blue limestone." Below this the limestones are grayer, are apparently somewhat dolomitic, and carry a few dark gray or black cherts.

Weber formation.—This formation consists principally of dark carbonaceous and calcareous shales and thin limestones. It contains abundant fossils of Coal Measure types. Its thickness varies from 100 to 550 feet, and, inasmuch as it succeeds a distinct unconformity, the variation may be due to the fact that where it is thinnest only the latest of its deposits accumulated. The limestones, which predominate in the lower part of the formation, are generally dark in color, fine grained, and of muddy texture, with calcite veinings. When metamorphosed they become black, and are altered to an impure marble. The top of the series is taken at thin beds of calcareous grits, resembling those of the succeeding formation. The greatest development of the formation is found from one to two miles west of Cement creek, opposite Point Lookout; while a few miles to the east, along Deadmans gulch, its minimum thickness occurs.

Maroon conglomerate. The Maroon conglomerate is so called because of its typical development on Maroon creek, north of the area mapped. In this series are included all the beds in this field above the Weber formation up to the unconformably overlying Gunnison sandstone, having an observed maximum thickness of over 4,500 feet. They are separable into an upper and a lower division. The lower division is an alternating series of yellowish gray grits, thin limestones, and shale beds, reaching 2,000 feet in thickness in their greatest development along lower Cement creek. The grits consist of grains and pebbles of quartz and limestone, with a calcareous and somewhat ferruginous cement. The limestone pebbles are irregular in distribution, some layers being made up almost entirely of them, and they frequently contain Coal Measure fossils. They vary in size up to 3 or 4 inches in diameter, while the quartz pebbles are generally less than 1 inch in diameter, the whole lower division being of finer materials than the upper. The limestones of the lower division occur in beds from 1 to 15 feet thick, are of bluish gray color and are frequently fossiliferous. The shales are in thin beds and are more prevalent in the southern part of the area.

The upper division, with an observed maximum thickness of about 2,500 feet at Mount Teocalli and Double Top, is composed of alternating beds of conglomerate and sandstone, with some shales and occasional limestone beds. The pebbles of the conglomerate, which are frequently of considerable size, sometimes several inches in diameter, consist largely of red granite and schist from the Archean areas, with representatives of quartzites and limestones of the older sediments. The limestone pebbles resemble those of the lower division, but occur in smaller proportion. The sandstones are usually massive, but at times thin-bedded from the development of shaly material.

The upper division is of a peculiar red or chocolate color, except in regions of local metamorphism, where greenish hues, arising from the development of minerals containing lime and iron silicates, affect the general appearance. In color and lithological character it resembles the Red Beds, which in some other parts of Colorado have been regarded as of Juratrias age, but as in this field no part of the formation can, on the evidence of fossils, be assigned to other horizons than the Carboniferous, it has all been mapped as of that period.

The upper division is found in greatest thickness in the northern part of the region mapped, where very considerable areas are bleached and metamorphosed. The very great decrease in the thickness of this division in the southern portion may be due to erosion or to absence of some of the lower strata in consequence of overlap.

JURATRIAS STRATA.

Gunnison formation.—This formation, which rests unconformably on the eroded Maroon conglomerates or, in some cases, on older formations, consists of quartzites and shales, with a little limestone, having an aggregate thickness of 300 to 450 feet. At its base is a heavy white quartzite, 50 to 100 feet thick, usually in a single bed. Above it, in some cases succeeded by other sandstone layers, is a blue limestone containing abundant fresh-water shells of the genera *Limnea*, *Valvata*, and *Cypris*. The remainder of the formation consists of gray, drab, pink, and purple clays and marls, through which run thin intermittent beds of drab limestone.

The assignment of this formation to late Juratrias age is based upon its stratigraphic and lithologic correspondence with the Atlantosaurus beds on the eastern flanks of the Rocky mountains and upon the similarity of its molluscan fauna to that of those beds, although in this more western region no vertebrate remains have yet been discovered in it.

CRETACEOUS STRATA.

Dakota formation.—This formation, which lies at the base of the upper Cretaceous, is throughout the West a white, quartzitic sandstone, with a fine grained conglomerate at the base, formed of very well rounded pebbles of the most dense and resisting siliceous material, generally light or dark chert and jasper. As a rule it carries abundant dicotyledonous plant remains, but no other forms of life. In the present field it varies in thickness from 50 to 300 feet. The white quartzite generally occurs in one or two benches, with seams of clay near the middle. The conglomerate at the base of the quartzite is usually 2 to 5 feet thick. A second fine grained conglomerate, whose pebbles are variously colored cherts and jaspers, occurs below this, separated from the quartzite by a stratum, sometimes 50 feet thick, of greenish clays resembling those of the Gunnison formation, to which they may belong. Toward the top the Dakota quartzite becomes shaly and alternates in thin layers with the dark sediments of the Benton formation.

Benton shale.—This formation consists of 150 to 300 feet of dark, almost black shales, with a few bands of fossiliferous limestone, 1 to 5 feet thick, which occur chiefly in the upper part and have a strong bituminous odor. Its most common fossils are *Inoceramus problematicus* and *Scaphites warreni*. Ironstone concretions from 6 inches to 3 feet in diameter occur here and there throughout the formation.

Niobrara limestone.—This formation consists of 20 to 40 feet of limestone overlain by 80 to 160 feet of shale. The limestone is light drab or gray, thinly and evenly bedded in layers 1 to 3 feet thick. The shales are somewhat calcareous. They are gray in color, generally having a thin yellow band at the top. Molluscan fauna and fish remains are found at all horizons of the formation. *Ostrea congesta* and *Inoceramus deformis* are common.

Montana formation.—The Montana formation includes the Pierre shales and Fox Hill sandstones, described by Hayden. The dividing line between these two subdivisions of Cretaceous strata, rarely susceptible of exact definition, is so uncertain in the Elk mountain region that they have not been distinguished on the maps. In the field the finding of characteristic fossils is often the only means of finally determining whether a given bed belongs to one horizon or the other. The most common mollusks of the Pierre in the Elk mountains are *Inoceramus barabini*, *I. sagensis*, *Placenticeras placenta*, with *Baculites* and *Scaphites*, and of the Fox Hills, *Mactra holmesii*, *Cardium speciosum*, and *Nucula*. The maximum thickness of the entire Montana formation is about 2,800 feet.

The Pierre division is composed mainly of a series of leaden gray clays, with numerous lenticular bodies of limestone, 1 to 2 feet thick and rarely more than 6 feet in horizontal dimensions, which are the chief source of the fossils. The clays are very hygroscopic and develop a series of characteristic surface cracks upon drying. In highly metamorphosed regions, as in the valleys of East and Slate rivers and near the mouth of O-Be-Joyful gulch, they are altered into bluish gray, siliceous slates with cuboidal fracture.

The Fox Hills division consists of alternating clays and sandstones, the former more arenaceous, as a rule, than those of the Pierre. The clays carry limestone concretions, which are similar to those of the Pierre, but yield a different series of fossils. The sandstones are slightly ferruginous and of yellowish gray color. The heaviest sandstone beds, which in places reach 30 feet in thickness, occur near the top of the formation. They are all somewhat fossiliferous, the upper stratum being especially productive.

The most complete development of the Montana formation in the area mapped is on the eastern slope of Mount Wilkinson, where there appear to be about 2,500 feet of Pierre beds and 300 feet belonging to the Fox Hills division.

Laramie formation.—This formation is a succession of sandstones and shales reaching a maximum thickness of 2,000 feet in this area. This thickness is in places reduced to 900 or even 600 feet, a portion of the reduction being due, doubtless, to erosion previous to the deposition of the succeeding series of beds. The sandstones occur throughout the formation, but they predominate in the lower portion, where they are also more heavily bedded and persistent, single benches reaching 30 feet in thickness. They are distinguished from those of the Fox Hills by greater purity, whiter color, and looser texture. Interbedded with the sandstones in the lower 450 feet of the formation occur the beds of workable coal. Four or five distinct seams, from 6 inches to 10 feet in thickness, have been recognized in some places, but generally not more than two are workable in the same locality. The coals vary in quality from dry bituminous through coking coal to anthracite.

Plant remains are frequently found in both sandstone and shales, but are most abundant next to the unaltered coal seams. Molluscan remains of brackish-water or fresh-water origin occur somewhat sparsely distributed throughout the series.

Ohio formation.—This formation consists of about 200 feet of sandstones and conglomerates, which rest unconformably upon the Laramie.

The conglomerates, which predominate in the lower part, are made up of pebbles of quartz and variously colored jaspers, with some of clay at the very base derived from the Laramie formation. The chert pebbles sometimes contain casts of crinoid stems, suggesting that they may have been

derived from Carboniferous strata. The sandstones are gray, weathering buff and red, and are made up almost wholly of coarse, loosely agglomerated grains of quartz. This formation has been recognized only around the base of Mount Carbon, in the southwestern portion of the Anthracite sheet, and on Gibson ridge. In the northern two-thirds of the area the succeeding Ruby beds rest directly on the Laramie. No organic remains have been observed in this series of beds.

Ruby formation.—This is the most recent pre-Glacial formation occurring in the area of the Anthracite sheet. No fossil remains have been found in it, but it has been assigned to the Cretaceous for the reason that it rests conformably upon the Laramie and is older than the Wasatch (Eocene), which overlies it west of this area. Its maximum observed thickness in Mount Owen and Ruby peak is about 2,500 feet, but it has been extensively eroded and is much thinner elsewhere. It consists of red, purple, and green sandstones and shales, with a few beds of conglomerate made up, for the most part, of debris of various eruptive rocks. The conglomerates, which appear at numerous horizons, are generally only a few feet in thickness. The basal conglomerate, however, is from 20 to 30 feet thick, and consists mainly of chert or quartz pebbles, with a few of Archean rocks. The cherts are white, black, or red, and some contain cavities formerly filled by crinoid stems, which were derived originally from Carboniferous rocks and resemble those occurring in the Ohio conglomerate. Igneous material is found with the other in subordinate amount at the base of the conglomerate, but predominates toward the top. In the other conglomerates the pebbles are of igneous rocks, but those of quartz and chert are sometimes found. Quartz sand is mixed with that of the igneous rocks throughout the series, increasing in amount in the upper part. The igneous rocks were originally porphyrites and andesites, but the constituent minerals are usually much decomposed, especially the biotites, hornblendes, augites, and magnetites, the hydrated oxide of iron being deposited in the space of the original crystals or in the matrix of the conglomerates, producing purplish or reddish tints in the rock. Where iron-bearing silicates, such as epidote, have been formed the rock assumes a greenish tint, and where the iron is leached out it becomes almost white. In some of the reddish beds epidote is developed at certain centers, producing green, nodular masses. Near Mount Marcellina a prominent product of secondary alteration is a dark red mineral which has been determined by Mr. R. C. Hills as red heulandite.

In the vicinity of the dikes these rocks are much indurated, and some of their finer grained beds, rich in iron, have become dense, red rocks with flinty fracture.

The Ruby beds are found in best development along the summit and southwestern slopes of Scarp ridge and of the Ruby range, and extend westward from the latter to and beyond the limits of the area mapped, finally disappearing beneath the beds of the Wasatch (Eocene) formation.

DISTRIBUTION AND STRUCTURE.

ANTHRACITE SHEET.

The area represented on the Anthracite sheet is a region of gently folded, sedimentary beds of Cretaceous age, through which an immense number of eruptive bodies in the form of laccolites and dikes have been intruded, producing local deformation and considerable faulting, with both contact and regional metamorphism.

The broader, underlying features of the structure can be traced to the effects of two important mountain-raising elevations just beyond the limits of the area mapped: the Treasury mountain dome or quaquaversal, and the fault-fold of the Elk mountains.

Treasury mountain, whose uplift has had the most widespread effect upon the structure of the region, is a dome-shaped elevation lying north of Slate peak, about 2 miles beyond the boundaries of the map. It consists of a central mass of Archean rocks from which the sedimentary beds, in rudely concentric circles, dip away at angles which decrease with distance from the center.

The axis of the Elk mountain fold, whose structure is shown on the Crested Butte sheet, runs in a northwest direction about 4 miles northeast of Gothic mountain. The effect of this uplift in the eastern part of the Anthracite sheet is a slight fold of the sedimentary rocks, producing but little modification of the regular dip from Treasury mountain. The Treasury mountain uplift is an older feature in the orographic history of the region than the Elk mountain fold, and the intrusion of the various laccolites and dikes is more recent than either, but in the resulting structure it is not always possible to differentiate the effects of the respective movements.

The present topographical structure of the region is the result of long continued erosion, which has acted most rapidly on the softer and less resisting rocks, leaving the great dikes and laccolitic masses and the indurated sedimentary beds in mountains or ridges. But the present stream beds do not in all cases avoid these more resisting masses of rock; in some places, such as lower Anthracite and Coal creeks, the streams cut into or across them, having originally assumed their courses in the softer beds which once completely covered the eruptive masses. It is not possible to make more than an approximate estimate of the amount of post-Cretaceous erosion, for the thickness of the beds which once covered the region can not be determined. Sediments at least 6,000 feet thick have been carried away from certain parts of it, and perhaps nearly double this amount has been removed.

Some description of the more important geological features is necessary to supplement the facts graphically set forth on the various maps.

Northeastern region.—The arc of a circle having a radius of about 6 miles drawn from Treasury mountain as a center, and including the Slate river valley to a little below Pittsburg and the mountain ridges on either side, as well as those bounding the head of Dark canyon, would enclose the area in which the influence of the Treasury mountain uplift is most distinctly shown. Within this area the beds dip away from the central uplift at an angle of 15° on the periphery, which increases to 25°, and in some places to 45°, near the center. In strike they vary from a little north of east through east and west to a little north of west. The steeper angles of dip are found in Cinnamon mountain, where a large mass of eruptive diorite is thrust into the sedimentary beds. Outside of this area, to the south and southwest, prevailing southerly and southwesterly dips continue with generally decreasing angles as far as the valleys of Coal and Anthracite creeks, beyond which southward the strata rise toward the adjoining laccolitic bodies. Section C, on the sheet of structure sections, shows the general disposition of the beds affected by the Treasury mountain uplift.

On the eastern slopes of Mount Baldy, around Gothic mountain, in the upper part of Washington gulch, in Anthracite mesa, and in the ridges bordering Slate river valley on the southwest are secondary flexures with axes parallel to the axis of the Elk mountain fold, whose influence on the present topography is seen in the general northwest trend of the valleys and intervening ridges in this part of the region. The general effect of the compression of the beds against the Elk mountain uplift is shown in section A.

The whole region is traversed by an immense number of eruptive dikes and fault planes, comparatively few of which could be represented on the map. Their strikes have such varying directions that it is difficult to detect any regular system, but the greater number appear to follow the two trends of northeast and north by east, which are radial respectively with the Elk mountain and Treasury mountain uplifts, or a trend which is the resultant of these two. The planes of the faults are usually vertical and the displacement is slight, being rarely over 100 feet. In Scarp ridge, where conditions are most favorable for the detection and measurement of these faults, the displacement is usually an upthrow to the west or north. That the faulting was not all synchronous is shown by the fact that the fault planes are often broken by later faults, especially by slip faults, or those whose planes conform to the bedding. The latter were observed in many parts of the region, notably under the Gothic mountain laccolite, which has been thereby moved slightly westward on the underlying Pierre shales; also at the base of the Laramie in Dippold basin, and at various points in Scarp ridge. As displacements along a bedding plane produce no discrepancy in the succession of beds, such faults are necessarily less easy to detect than those which cut across the bedding planes.

Anthracite mesa.—The structure of this little ridge is important because of the valuable beds of anthracite coal which it contains. The coal basin, which occupies the higher portion of the nearly flat-topped ridge, formed part of the northwestern member of a syncline, the greater part of whose trough has been carried away by the erosion of Slate valley. On the northeastern edge of the basin the strata have a dip of 22° to 26° southwest, which declines to 5° or less in its southwestern limb, the average strike being about north 30° west, or a little nearer north than the trend of the ridge, so that the steeper dips of the northeast side prevail in the southern end, where, through erosion of the Laramie beds, the Fox Hills sandstone is exposed. A multitude of small faults, generally with a displacement of but a few feet, cross the ridge in a northeast direction. There is also evidence of slip faulting in the character of the upper and lower layers of the main coal seam, which are crushed into angular fragments with striated faces for a distance of 3 to 5 inches from either surface.

Northwestern region.—The structure of the sedimentary beds in the northwestern corner of the Anthracite sheet has been distinctly affected by the intrusion of the great laccolite masses of Ragged mountain and Mount Marcellina, the former of which is exposed only to the north of the area mapped. On the southern slopes of this mountain the dip of the Laramie strata away from the mountain conforms in general to the angle of the present surface, reaching, however, an angle of 25° in the upper part. On the east the strata pass rapidly through a syncline which pitches southeast, into the southwesterly dipping strata upturned against the Treasury mountain uplift.

On the north of Marcellina the strata are gently upturned against this laccolite for a distance of only about a mile from the contact, and beyond that they slope upward toward Ragged mountain. There is also an anticlinal arch of the strata over the northern part of the laccolite, so that the Montana beds are exposed beneath the Laramie on the north walls of the canyon, in the axis and down the western slopes of the anticline.

On the east of Marcellina, at Prospect point, the Laramie strata are upturned at 30°, but pass under the Ruby beds in a horizontal position within a mile eastward, and then assume the regular west and southwest dip.

The deep canyon cut along the eastern and northern flanks of the laccolite by Anthracite creek, whose course was probably determined in the softer beds that once covered the eruptive body, has now reached a considerable depth in the mass of the latter. This furnishes a means of determining, by the relative position of the top of the eruptive on either wall of the canyon, the minimum slope of the original laccolite.

On the south of Marcellina immense talus slopes of eruptive debris obscure the beds at the immediate contact with the eruptive, but at a little distance they slope gently southward at angles of 5° to 10°.

Ruby range.—The uplift of the Ruby range, which is topographically the most important and striking feature of the area mapped on the Anthracite sheet, has had little or no effect upon the structural position of the sedimentary beds involved. The latter maintain throughout the uplift a comparatively regular and uniform dip to the south and west, at an angle which grows gradually less toward its southern end. Although the sedimentary beds are extensively fractured, and in some cases slightly disturbed at the immediate contact with the larger bodies of eruptive rock that have cut through them, the amount of the displacement or deformation is comparatively insignificant. The superior resistance to erosion offered by the great number of eruptive dikes, and by the adjacent sedimentary beds indurated by the metamorphism attendant upon their eruption, is the cause of the existence of this remarkably narrow and precipitous mountain ridge, which in a linear extent of less than 7 miles has as many peaks of nearly or quite 13,000 feet elevation. Metamorphism has in many cases so altered both sedimentary and eruptive rocks as to make them almost indistinguishable; and among the altered sedimentary rocks, where the original lithological characters as well as the fossil contents of the beds are in a great measure obliterated, the tracing of geological horizons requires the greatest care and circumspection on the part of the observer. The beds which are most readily recognizable, and hence of greatest value for this purpose, are the conglomerates, such as the conglomerate at the base of the Ruby beds, and the coarser and more massive sandstones of the Laramie and Fox Hills horizons. These generally form the beds of the principal glacial amphitheaters, or so-called "basins," which are a characteristic feature of the topography of the region.

The metamorphic action, which is directly traceable to the influence of a contiguous body of eruptive rock, appears to have extended but a short distance in directions parallel with the stratification planes, and much farther across the bedding. In other words, more widespread alteration has resulted from the vicinity of intrusive sheets that occupy a position parallel with the stratification than from dikes that cut across it.

Southern area. In the southern third of the Anthracite area there is a general rise of the sedimentary beds toward the south. A certain portion of this rise is directly traceable to the influence of the various laccolitic intrusions; it is known, however, that there is a general slight rise of the Mesozoic beds toward the Archean rocks that are exposed along the Gunnison river and its tributaries, 15 to 20 miles south and east of the present area, to which the northwest dips beyond the laccolitic bodies in the southeastern corner of this area are attributable.

Between Marcellina and Mount Beckwith the Ruby beds lie in a broad syncline whose axis is about 2 miles south of the former peak. In the southern member the strata rise with gradually increasing angle, which reaches 25° at the immediate flanks of the latter. Mount Beckwith is a double laccolite, only the eastern half of which is shown on the present map. The western half and a narrow connecting band of eruptive rock lie just west of its boundary, and in the reentrant angle between the two laccolites the strata are compressed into a northward-pitching syncline and are upturned at an angle of 45° against the flanks of either laccolite. Only the eastern member of this syncline comes within the limits of the map. South of Mount Beckwith, along Cliff creek, the strata occupy a comparatively undisturbed position, lying either horizontal or having a dip of 5° to the north or northwest.

The intrusion of the igneous rocks of the Anthracite range has had more disturbing influence on the sedimentary beds along its northern flank than that of any other of the laccolitic bodies in the present area. This may be ascribed in part to the fact that several intrusive sheets, probably offshoots from the central mass, and in one case reaching 500 feet in thickness, have been forced in between the strata. Erosion has entirely removed the Ruby beds from the slopes of the range toward Anthracite creek, and also a portion of the Laramie beds, down to the coal measures. At a few points the tops of the Fox Hills formation are exposed. The general inclination of these beds is from 15° to 25°, steepening near the eruptive body and shallowing toward Anthracite creek, which occupies approximately the axis of the syncline. Beyond it the dip changes quite abruptly to 5° and 10° south and west.

The strike of the beds along the northern flank of the range is north 15° to 25° east, becoming nearly northeast at the western extremity of the range, where the strata are upturned at 60° to 70° against the laccolite. Between its western end and Beckwith pass this steep dip changes abruptly to a horizontal position of the beds.

On the south flanks of the Anthracite laccolite the sedimentary beds are for the most part buried beneath the talus slopes or the West Elk breccia, but the evidence that could be obtained tends to show that they are comparatively undisturbed.

The topographical basin at the head of Anthracite creek, included between the slopes of the Ruby range, Scarp ridge, Mount Axtell, and the Anthracite range, corresponds approximately to a geological basin or syncline whose beds dip in general toward the center from the north, east, and south and include a number of minor folds. It is thus a sort of center of structural disturbance, and in the vicinity of Irwin the strata are broken by an intricate network of small faults, many of which are mineralized and constitute the veins of rich silver minerals for which the district is noted. Only a few of the more extensive and prominent faults have been indicated on the map.

The Mount Axtell laccolite differs from the

others thus far mentioned in that the adjacent sedimentary strata have apparently not been disturbed by it, and furthermore, in that to the north it passes into a comparatively thin intrusive sheet which is folded with the enclosing sedimentary strata. The absence of deformed strata around it may be due to the fact that its greatest horizontal extension is at a relatively higher geological horizon (here the contact between the Laramie and the Ruby formations) than those of the other laccolites, and therefore the strata which were domed up by its intrusion have been entirely eroded away.

The bed of Coal creek, which crosses the northern slopes of the laccolite where it passes from the state of laccolitic body into that of intrusive sheet, occupies, as has already been stated, approximately the axis of a synclinal basin. On the southern slopes of Scarp ridge the underlying sedimentary beds and the lower surface of the eruptive sheet dip 23° south-southeast, while the upper surface of the latter dips 12° east-southeast, showing a thickening of the latter to the westward. The axis of the syncline, which has a general trend north 30° east, crosses Coal creek near the bend a few miles above the town of Crested Butte. Southwest of this, around the laccolite of Mount Wheatstone, only the western point of which appears within the limits of the present map, an average dip of 8° to 10° northwest is maintained, interrupted only by a few minor flexures.

The Wheatstone laccolite, so far as can be observed, has not disturbed the strata at present in contact with it to any considerable extent, though they are somewhat fractured on its southwestern flanks along upper Carbon creek. Its base sometimes follows a stratigraphic plane and sometimes cuts across several hundred feet of strata at a low angle.

The intrusion of the Mount Carbon laccolite has exerted considerable disturbing force on the adjoining sedimentary beds, especially on its western side. Along the eastern side of the upper Ohio Creek valley the Ohio and Laramie beds are upturned against it at 45°, and show some secondary folding and faults, but shallow in dip to 5° on the western side of the valley. They also show a tendency to wrap around it, changing in strike from 25° northwest on the southwest side to 30° northeast on the northwest slope. To the northeast and east the sedimentary beds appear to retain a normal dip to the north and west, with a strike to the east and northeast, the eruptive mass apparently cutting across the ends of the strata without producing any considerable deformation, though the immediate contact is rarely to be seen.

On the south, in the area between Ohio and Carbon creeks, where in the vicinity of Baldwin considerable coal mining has been done, the Laramie beds are compressed into several parallel folds, with an axial trend of north 50° to 80° east. The two anticlines observed have gentle dips except at one point in the northern fold, where a northerly dip of 55° was observed. In an east and west direction they apparently do not extend much beyond the bounding valleys.

Down stream, to the south and east, the lower Cretaceous horizons soon appear from beneath the Laramie beds, with a gentle dip to the northwest.

The Laramie measures in the vicinity of Mount Carbon are thinner than in any other part of the field, a boring near the end of the railway in Ohio creek valley showing 650 to 900 feet of Laramie strata with 200 feet of overlying Ohio beds. There may have been a less thickness of Laramie beds originally deposited here than in the portion of the area nearer the mountains from which the sediments were derived, but inasmuch as the coal measures show no decided change in thickness, it is more probable that the variation is mainly due to erosion prior to the deposition of the Ohio and Ruby beds.

To the west of Mount Carbon, and south of the Anthracite range and Mount Beckwith, the greater part of the area is occupied by the West Elk formation, which apparently rests unconformably upon the eroded surfaces of the Ohio, Ruby, and Laramie formations, and possibly also of the laccolitic bodies, though, owing to the general covering of debris, its contact relations can not be distinctly determined. The bedding planes of this formation generally occupy a horizontal position, but display a few gentle and unimportant flexures. In the area west of Storm ridge there is a general dip of 5° to the northwest toward Cliff creek.

CRESTED BUTTE SHEET.

The area represented on the Crested Butte sheet is divided by the valleys of East and Slate rivers, which cross it diagonally from northwest to south, into two unequal portions, which are strongly contrasted in geological structure. Both are mountainous regions, but in the one case the mountains are almost entirely the result of cutting down by erosion, whereas in the other they result from uplift and erosion combined.

In the smaller, southwestern area the sedimentary strata still occupy an approximately horizontal position, the higher peaks resulting from the greater resistance to erosion offered by masses of eruptive rocks intruded between the beds without greatly disturbing them, and the present surface of this area is covered by rocks of more recent age than the Dakota formation.

The eastern area was originally uplifted to a much greater elevation, but erosion has eaten into it more deeply, so that although the resulting mountain forms are only a thousand feet higher on the average than those of the southwestern region, the present surface is mainly occupied by Paleozoic or older rocks.

This area forms a part of the broad Elk mountain uplift, which has a general north-northwest trend, nearly parallel with the western flanks of the older Sawatch uplift, and appears to have been forced into its present position by compression against the Archean buttress of the Sawatch. This compression has been intensified by the intrusion of immense masses of diorite, which, instead of welling up and spreading out gently between the strata, were forced violently into and across them, catching up immense fragments of the sedimentary beds within their mass, and pushing adjoining portions into reversed folds and faults.

The general facts of the structure are represented on the areal and structural maps, but some detailed description of the geological conditions prevailing in different portions of the area will facilitate their comprehension.

SOUTHWESTERN AREA.

The basalt cap of Mount Wilkinson rests on an eroded surface of Laramie and Montana beds dipping gently northwestward, so that 100 to 200 feet of the Laramie is exposed beneath the northwestern extremity of the basalt sheet, but it does not appear along the southeastern side. The basalt flowed over an uneven surface, and on its southern face there lies between it and a thin sandstone forming the lowest bed of the Laramie a deposit of coarse gravel, containing rolled pebbles of nearly all the sedimentary and eruptive rocks to the north, including the Archean. This gravel is probably the relic of an ancient stream bed or morainal ridge.

The whole Montana formation is well exposed on the eastern slope of Mount Wilkinson, with the Niobrara limestone at its base along Slate river valley. The Laramie beds form its northwestern slope, and reach their maximum thickness in this region along Carbon creek. These beds all dip gently northwestward from 5° to 15°, and their position is not visibly affected by the Mount Wheatstone laccolite. On the northern flanks of Mount Wheatstone, in Gibson ridge, the Laramie strata appear, dipping 8° to 12° north-northwest, and are capped by a small patch of the Ohio formation.

In the area between Slate and East rivers, around the great laccolites of Crested butte and Gothic mountain, the Pierre beds of the Montana formation occupy comparatively undisturbed positions, being either horizontal or dipping 2° to 5° to the southwest. The strata are altered only at the immediate contact with the eruptive bodies. Some evidence of horizontal displacement is observed in this region, especially at the base of Gothic mountain, where the porphyry rests on the clay shales. In the point of the ridge between Washington gulch and Slate river the beds are locally disturbed and the Fox Hills sandstone dips 25° southwest, striking northwest with the trend of the ridge. Meridian lake, on the east slope of this ridge, occupies a peculiarly narrow, strike valley, which was formed in the clays below these sandstones, either by faulting or by glacial erosion. It has no normal inlet or outlet, its overflow escaping through a narrow notch on its eastern bank.

AREA EAST OF SLATE AND EAST RIVER VALLEYS.

The mountains of this area are due to four distinct uplifts. On the northwest is White Rock; on the northeast is the single mass of Italian and Taylor peaks; in the extreme south is Cement mountain; and Double Top is in the middle of the district.

White Rock uplift.—The White Rock mountain mass forms the southeastern end of what has been called the great fault-fold of the Elk mountains. Its characteristic structure, which is shown in the structure sections A and B, is that of sedimentary strata upturned at steep angles, or even overturned against the southwest flank of the central diorite mass, so as to dip towards it, whereas on other sides they seem to have been lifted bodily upward by the force of the diorite intrusion and still occupy an approximately horizontal position. The diorite was evidently forced up through ragged fractures across the sedimentary series, for its contacts, though generally with the Maroon formation, follow no one stratification plane, and innumerable large, irregular fragments or masses of the sediments are found enclosed in the diorite. These are highly metamorphosed, so as at times to be scarcely recognizable as of sedimentary origin.

In the high mountains north of the diorite mass, along the northern boundary of the map, the Maroon beds dip 5° to 15° northwest, and belong in general to the upper division of this formation. These rocks are highly metamorphosed in large areas, and have there lost their characteristic red color.

In the steeply upturned beds along the western flanks of the diorite body, facing the valley of East river, both divisions of the Maroon formation are exposed. The thickness of the lower division remaining above the diorite mass, however, varies considerably from point to point with the irregular contact at the bottom, while that of the upper formation varies with the irregular overlap of the unconformable Gunnison beds.

The most regular and complete section of these upturned beds is found in the gorge of Copper creek, which cuts the formations at right angles. Here, at the base of the Niobrara limestone, as shown in section A, is an intrusive sheet of eruptive rock, which follows the stratification planes with remarkable regularity at the outcrops, but gradually wedges out to the north and south and disappears within a couple of miles in either direction. It conforms in dip with the enclosing sedimentary beds, and has apparently been upturned with them. The dip of the beds, which at the mouth of the gorge is about 35° southwest, increases to 50° or 60° as the diorite body is approached. In the opposite direction it lessens still more rapidly, becoming horizontal on the other side of East river valley at the base of Gothic mountain.

To the north of Copper creek, in the Avery peak region, the strata curve in strike around to the northeast, and in Rustler gulch, just beyond the boundary of the map, the lower Cretaceous quartzites and clays extend eastward almost to a contact with the diorite, probably as the result of an overthrust. On the slopes of Avery peak the upper strata of the Maroon formation consist of thin bedded, light red sandstones, which more closely resemble the so-called Triassic Red Beds of the Rocky mountain region than any others observed in this district. They probably represent a higher horizon, which is elsewhere covered by the Gunnison formation.

South of Copper creek, on the ridge at the head of Queen basin, there is a sudden change in the dip of the beds. From an angle of 50° to 60° southwest the dip changes in a very short distance to an overturn, with an angle of 60° to 80° northeast, the strike remaining constant in a northwest direction. These conditions continue for a little over 3 miles southeastward, to near the head of Deer creek, where a sharp secondary anticline is developed in the ridge west of this creek, making a double fold instead of the single reversed fold, and producing a sharp outward curve in the outcrops of the Mesozoic beds, and a widening and reduplication of the Maroon beds, which in the valley of Deer creek are compressed into a vertical position. Southeast of Deer creek the latter are overturned and apparently pushed over the Mesozoic beds by an overthrust fault, so that they are brought into contact with the Niobrara limestone, and thus the continuity of outcrop of the lower Cretaceous beds is broken.

South of the great White Rock diorite mass, a line drawn along West Brush creek to the summit of Double Top forms approximately the dividing line between the region of sharply upturned and folded beds on the southwest and that of the nearly horizontal beds on the northeast. The contrast between the types of structure is most clearly seen in the Maroon formation of West Brush creek, at the south base of Teocalli mountain. Here the valley bottom is cut into vertically upturned beds, but on the almost overhanging summit of Teocalli the same strata occupy a nearly horizontal position, dipping 2° to 5° east. Toward the valley of Middle Brush creek they rise again to the eastward, with an average dip of 10° to 15° southwest, which continues until the disturbed region around Italian peak is reached.

The valley of West Brush creek appears to correspond approximately with the line of a steep, monoclinal fold, in which the beds pass from a vertical to a horizontal position, and which as it approaches the diorite body may become an actual fracture. The steep dips, however, extend for some little distance above the valley on the western flanks of Teocalli ridge.

Italian peak region.—Italian peak, Mount Tilton, and Taylor peak form part of a line of uplift which follows the western flanks of the Archean mass of the Sawatch in a north-northwest direction as far as Aspen, and is characterized by extreme compression and faulting of the sedimentary beds. In the present topography the slopes of the Sawatch range are separated from these peaks by the broad valley of Taylor river, which lies east of the limits of the area mapped, but which through its west fork drains the amphitheater between Star, Taylor, and Tilton peaks.

Along this line of uplift the lower Paleozoic beds are sharply upturned against the Archean and are broken by a series of strike faults, which have a uniform upthrow to the west, with displacements of 50 to 600 feet. Only the point of the easternmost of these faults appears on the map. Of the others, two are parallel, and a third, which crosses them diagonally in a northerly direction, has a displacement of 600 feet at one end and apparently disappears to the south in the Weber shales. The small cross fault between Mount Tilton and Italian peak has a horizontal displacement of 100 feet.

The intrusion of the great diorite mass of the Sawtooth range, which forms the summits of both Star and Taylor peaks, has as a rule but slightly affected the position of the adjoining sedimentary beds, except when they are almost enclosed in it. The westerly dipping strata on the east face of this range stand at angles of 40° to 60°, and are but little steeper than the beds to the north and south. In Mount Tilton the dip of 45° west is maintained for both faulted and non-faulted strata. Immediately north of North Italian peak, in the vicinity of the eruptive masses, the strata dip from 75° west to 50° east, being overturned. The limestones in contact with these eruptives have been intensely metamorphosed, giving rise to the formation of vesuvianite, garnet, pyroxene, scapolite, epidote, and other minerals. The tongue of sedimentary beds included between the granite and diorite bodies of Italian mountain is almost wholly made up of these minerals. For a mile west of these eruptive bodies the sedimentary strata either stand vertical or are slightly overturned, with a dip of 70° to the east.

In the region about the heads of Taylor, Cement, and East Brush creeks, lying between the eruptive masses of Italian mountain and the Sawtooth range, the beds are thrown into minor folds with varying strikes, and are often much contorted and broken. The prevailing strike is, however, in a north-northwesterly direction, with a southwest dip, and the angles of dip rarely exceed 25°. A fault line can be traced across this area from the eastern point of the White Rock diorite body nearly to the diorite of Italian peak. As it lies entirely within the Maroon formation its displacement could not be accurately determined, but it has apparently a downthrow of about 300 to 600 feet to the north. The patch of Gunnison and Dakota beds lying on the southwest slopes of Hunters hill probably indicates the easternmost extent of those beds in this region. They now dip 25° eastward, or into the hill, and show no angular unconformity with the Maroon beds on and against which they rest. It would therefore

appear that they were originally deposited at the foot of a steep bluff, and on a much eroded surface of Maroon beds. At their northern end, in contact with these beds, a small body of Benton clays, brought down by the movement of the fault, has escaped erosion.

Double Top region.—Between Italian peak and the ridge extending from Double Top along the west side of Cement creek valley toward Star peak, the Maroon beds lie in a broad synclinorium, which extends southwestward for several miles, beyond the limits of the map, gradually rising toward the Archean exposures of Taylor creek valley. In this area the beds have a gentle dip, rarely exceeding 20°, and a prevailing northwest strike.

The summit of Double Top and its western slopes toward Slate river valley show a series of anticlinal and synclinal folds, with northwest axial trend, which partake in part of the structure of the steeper, western side of the Elk mountain fold and in part of that of the Cement mountain uplift.

A typical cross section is that taken on a line running along the valley of Beaver creek to the summit of Double Top. East of Slate creek the beds dip gently west, at angles of 10° to 15°, to within half a mile of the forks of Beaver creek. There they rise abruptly to the crest of a sharp anticline, and as abruptly descend into a syncline. The vertical beds of the eastern arm of this syncline form bluffs on the west wall of the valley of the north fork of Beaver creek, while the valley itself occupies the eroded axis of the adjoining anticline. On the northwest shoulder of Double Top lies a patch of Gunnison and Dakota strata, in nearly horizontal position. They form part of a shallow syncline extending northward to Cascade creek, while the summit of Double Top itself is the crest of a broad anticline.

The individual folds apparently die out both to the north and south, or are taken up by other folds, en echelon, or by small faults. In the angle between the northwestern and the southern trends of the general mountain uplifts, along Cascade creek, the structure is much more complicated and the folds are replaced by faults. The relations are, moreover, obscured by general overthrust of the Carboniferous beds over the Mesozoic.

To the south of Beaver creek the short anticline and syncline above described can be traced for some distance on the western slopes of Point Lookout, but they are lost before the valley of Cement creek is reached.

An interesting feature in this region is the evidence of the unconformity between the Maroon and Gunnison formations. Not only does the latter rest at different places upon different horizons of the former, but an actual discrepance of angle of dip as well as of direction of strike in the respective beds is observable along Beaver creek, on the shoulder of Double Top. This unconformity is still more clearly seen along the north wall of the valley of lower Cement creek, where, as one descends the stream, the base of the Gunnison quartzite is observed to rest on successively lower beds of the Maroon formation, until near its mouth the Gunnison is in contact with strata near the bottom of the Maroon.

Cement mountain uplift.—A line running northwest and southeast along the southwest boundary of the Archean exposures, divides the Cement mountain uplift into two portions differing essentially in structural conditions. To the southwest of this line the formations are steeply upturned, and only those strata above the Weber shale are exposed. On the northeast the exposures are mainly of rocks older than the Weber shale, and, though somewhat broken by faults, the beds are not sharply folded, but dip gently northward and eastward at angles generally under 25°. Two important structural facts are prominently brought out in this region: the unconformity and overlap of the Gunnison quartzite on the earlier formations, and the fact that an orographic movement took place here previous to the deposition of the Weber formation.

The structure of the southwest flanks of the uplift resembles that of the corresponding portion of the White Rock uplift in that the sedimentary beds are pushed up, with a general northwest trend, into a vertical or even overturned position, their angle of dip diminishing to the southwest toward the adjoining valley of Slate river, where it becomes less than 5°. The steep dip marks either a line of fault with an upthrow to the northeast or an ancient and abrupt shore-line along which there has been an overlap. Possibly unconformity and faulting are combined. The structure is complicated, however, by the intrusion, irregularly across the beds, of the rhyolite mass of Round mountain, causing further local displacement near its contact. From the mouth of Cement creek southward the Gunnison quartzite comes successively into juxtaposition with the Leadville limestone, the Yule limestone, and the Sawatch quartzite, the first having a northwest strike and a dip to the southwest, while the last two formations strike nearly east and west and dip 8° to 15° to the north.

Between the northern end of the rhyolite body and the Archean, the Gunnison and the underlying Maroon beds are compressed into a sharp anticline and syncline, with axes pitching to the northwest on the northern slopes of the ridge north of Granite creek, while in the bed of the creek itself, where the crests of the folds are eroded, the Maroon beds are found much contorted, assuming a vertical or even overturned dip as the Archean contact is approached. Remnants of the overlying Gunnison quartzite, disrupted by the intrusion, are found on either side of the mouth of the creek, still retaining their western dip. East of the main mass of Round mountain the Maroon beds rest upon the rhyolite, dipping eastward at 40° to 65°, with a strike of north 20° to 40° west. At the head of Slumgullion creek, between the south end of the rhyolite body and the Archean, is another syncline in the Gunnison and Maroon beds, which pitches sharply southward and soon runs out. Beyond this the beds lie in a sharp monoclinal fold against the Archean. At one point east of Slumgullion creek, where the upper part of the lower Maroon beds is exposed, only 100 feet of these strata is seen. Their outcrop widens southward, and 3 miles beyond the limits of the map a measured section shows a thickness of 2,620 feet of these beds, of which about 300 feet belong to the upper division.

In the main mass of Cement mountain, the sedimentary beds on the northwest slopes dip gently northwest and north; those on the north and northeast dip in these directions at 20° to 30°. The irregularities of outcrop noted on the map are the result of unequal erosion of the series of gently inclined beds, which are considerably broken by faults.

The Cambrian and Silurian exposures overlooking the head of Granite basin on the north are unusually thin, the Sawatch quartzite being reduced, mainly in the upper member, to 125 feet.

The principal fault of the region, which runs nearly north across the head of Granite basin to Cement creek valley, has a displacement of over 600 feet, with the upthrow on the east. It disappears beyond that valley, at the foot of cliffs formed of Weber shales. Although the latter and the overlying Maroon beds are slightly disturbed near the line of the fault, the actual displacement of the latter ceases at this horizon, and, as shown on the map, the outcrops of the Weber formation cross the ends of the Cambrian, Silurian, and lower Carboniferous beds, showing that the latter had been faulted, folded, and eroded previous to the deposition of the former.

South of Cement creek is a short fault, near and parallel to that above mentioned, which has an upthrow of 25 to 75 feet to the west. This fault, which follows the valley of lower Cement creek, has a maximum displacement of 400 feet, with an upthrow on the north. Two small faults which cut the Mesozoic beds north of the mouth of Cement creek have throws of 40 and 75 feet, the one to the north and the other to the south, respectively.

The fault running diagonally between Cement and East Cement mountains has an upthrow of about 280 feet to the southwest, the plane of the fault dipping 85° northeast. At one end it passes into a zone of parallel faults, of which eight are distinguished in a width of 600 feet, their throws being 30 to 120 feet each. A cross fault at the other end has an upthrow of 100 feet in the Sawatch and Yule beds.

In the two forks of Deadmans gulch, to the east of Cement mountain, a general northeast strike and northwest dip prevail, which gradually veer to a northwest strike and northeast dip near Cement mountain. A small fault which crosses the valley in a northerly direction has an upthrow to the east of 50 feet.

Hot springs, which have built up considerable mounds of calcareous tufa, are found in the valley of Cement creek at two points, which are indicated on the map. These springs issue from the lower Paleozoic limestones, and are nearly on the line of the Cement valley fault.

LARAMIE COAL MEASURES.

The coal measures consist of a series of sandstones and shales, and constitute the lower 450 feet of the Laramie formation. By local metamorphism the sandstones are changed to quartzites, the shales to slate, and the originally dry bituminous coals to coking coals or anthracite. The component strata of the coal measures vary in character and relative thickness from one part of the field to another. Still more variable are the coal seams, so that identification of the several beds exposed in different portions of the region is very difficult, and, indeed, often impossible.

On the Anthracite sheet there are four important coal areas: the northern slope of the Anthracite range, the western base of Mount Carbon, the region about Baldwin, and the Slate river field. The region of Dark canyon and the southwestern slopes of Ragged mountain are coal-bearing, but prospecting has hitherto failed to show beds of value.

The Anthracite range.—The base of the Laramie is here marked by a sandstone, from 10 to 30 feet thick, lying just above a succession of shale and thinner sandstone beds which carry traces of Fox Hills fossils. Over the lowest sandstones are others, interbedded with shale, in all between 300 and 400 feet. The sandstones predominate in the lower half of the series, the shales in the upper. The main coal seam, 2 feet 8 inches to 4 feet thick, occurs 115 feet above the base of the formation; a second, locally developed to a thickness of 6 inches, lies 100 feet higher. Near the summit of the coal measures the Laramie is interrupted by a heavy sheet of porphyrite, which extends for a mile or two along the range. Other eruptive sheets have been struck in deep prospecting. The coal of this area is anthracite. The beds dip to the north from 15° to 20°.

Mount Carbon.—The natural exposures of the coal series on the western slope of Mount Carbon are poor. However, in a tunnel driven at the creek level, opposite Mount Carbon post-office, three beds of coal are opened: the upper, 18 inches thick; 45 feet below this, stratigraphically, the middle seam, 3 feet 6 inches thick; and 250 feet below the latter, a bed 1 foot thick, underlain by 200 feet of considerably metamorphosed shale, which rests upon the eruptive rock. In this section the coal measures are composed of shale and sandstone, the former predominating. The strata have an average dip of 45° west, showing, however, a number of crumples. The coal is in part coking, in part a semi-anthracite.

The Baldwin region.—The coal measures here consist of sandstone and shale in beds from 5 to 20 feet thick, with three coal seams, 50, 200, and 300 feet respectively above the base, the whole far less altered than in other areas embraced by the Anthracite sheet. The basal member is a light gray, quartzose sandstone, 50 to 80 feet thick, resting upon a yellow sandstone carrying Fox Hills mollusks and characteristic fucoids. The lowest coal seam, or No. 1, lies directly over the basal sandstone. Overlying the upper seam, or No. 3, is a heavy sandstone, which closes the coal-bearing series. The coal beds all vary in thickness, but range from 3 to 6 feet.

In the east and west faces of the hill in the fork of Ohio and Carbon creeks, the lowest and the second (or middle) workable seams are visible. The former underlies the entire area between the creek bottoms, to the line of the Mount Carbon eruptive; whether it is of workable thickness throughout the area, however, is undetermined. The second or middle seam forms an outlier of limited area in the knoll to the south of the southernmost road between Ohio and Carbon creeks, outcropping near its summit; it reappears north of the east and west road from Baldwin, passing beneath the surface with a dip of 3° to 10° northward.

East of Carbon creek the coal measures form the bluffs of the valley as far north as the southern end of the Mount Carbon eruptive, a little over a mile north of Baldwin, what is probably the No. 2 seam being here exposed.

Slate river.—The coal measures of the Slate river valley form part of a field which once extended continuously from the slopes of Mount Wheatstone along the east face of Mount Emmons, across O-Be-Joyful gulch, and through the Anthracite mesa. A great part of this field has been removed by the erosion of the Slate river valley and its tributary gulches.

Three sections of the coal measures of this field are given in the columnar sections: one on the north side of Baxter gulch, the second at the Crested butte mines, the third at the Anthracite mesa. The vertical distribution of the coal seams in the three localities differs considerably, yet it is probable that the three principal seams in each are identical, the differences arising from the variation in thickness of the intervening sandstones and shales.

The basal member of the coal measures in the area is a white sandstone from 50 to 80 feet thick, which is locally somewhat shaly, but part of which always outcrops in a well marked bench. The No. 1 coal seam rests directly upon this sandstone.

On the Crested Butte sheet only two areas of workable coal beds exist: that in Gibson ridge, on the north of Mount Wheatstone, which forms part of the Slate river field; and that beneath the cap and on the west flank of Mount Wilkinson. The latter also includes the southern base of Mount Wheatstone, where, however, the measures are greatly fractured, and it is impossible to trace the coal beyond the immediate vicinity of its one or two exposures. At one of these a thickness of about 3 feet 4 inches was observed. On Mount Wilkinson the strata are comparatively little disturbed, and the coal has been prospected at several points in its eastern face, from 3 to 4 feet showing beneath the basalt in one locality. This is probably the lower seam, while that on Wheatstone is possibly the upper, No. 3, seam.

CHARACTER OF THE COAL.

In the area represented on the accompanying maps the coal varies between anthracite, semi-anthracite, and bituminous. The latter is both coking and non-coking. The non-coking bituminous coals are found in the regions of least metamorphism; the coking coals, in localities of more advanced alteration; and the anthracite, only in areas of great regional metamorphism or in the neighborhood of large bodies of porphyrite upon which the sedimentaries chance to rest or from which interbedded sheets extend into the adjacent strata. The fields of anthracite coal are the Anthracite mesa, Mount Emmons, O-Be-Joyful and Poverty gulches, Mount Carbon, and the Anthracite range. Of these the Anthracite mesa has long been worked. The chief area of coking coal is Gibson ridge, east of Mount Axtell, within the limits of the Crested Butte sheet. In the vicinity of the Mount Carbon eruptive one or two of the seams yield a coal possessing fair coking qualities. The dry bituminous coals are derived wholly from the Baldwin field.

For the analyses which follow, the samples were taken, not with a special view to represent the run of a mine, but, rather, to ascertain the variation in the composition of the coals in and between the several districts, with reference to the dynamic and eruptive influences that have been brought to bear upon them. The analyses do, however, very closely approximate the general run of the coals from which the samples were taken.

Analyses 1–3 are of coals most distant from metamorphic or eruptive influences, and they are nearest in character to the typical, unaltered Cretaceous coals. Analysis 8, which represents the entire seam of which 6 and 7 are benches, is also within the limit of variation of these coals. Analyses 6 and 7 indicate the differences that may exist between two benches of the same seam. Analysis 5 is of coal from the same seam as 8, but a half mile nearer and close to the eruptive body of Mount Carbon; the seam is cut by the porphyrite a few feet beyond the point of sampling. Samples 9 and 10 are from the No. 2 or middle coal seam, on the west side of Mount Carbon, 450 feet across the strata from the eruptive mass, while sample 11 is from the lower seam in the same locality, but only 203 feet from the underlying eruptive. The former is a coking coal, the latter an anthracite, and compared with each other and with sample 5 they illustrate the relative effect of the eruptive rock at different distances. In a

comparison of these different samples it is apparent that an eruptive body cutting across a coal seam affects its chemical and physical composition but a comparatively short distance from the line of contact, while where underlying it, even at a considerable distance, it affects the composition of the coal as much as where cutting it, and over an area limited only by the extent of the eruptive mass itself.

Samples 12–17 are of anthracite taken from the mine in the Anthracite mesa. The structure of this seam in this mine and in several of the neighboring prospects is peculiar. It shows a middle bench of solid, jointed coal, from 2 feet 6 inches to 4 feet thick, and an upper and an under bench of a highly fractured, chip variety, each varying from a knife-edge to 18 inches. This structure has arisen from movement on stratification planes, a phenomenon not infrequent in the region of upper Slate creek. Its effect upon the quality of the coal is seen in analyses 15 and 16 of the under and upper chip, in the high percentage of ash, which, however, is held as foreign matter in the interstices of the fractured coal, and is not of the coal itself.

Samples 28–31 are from openings in Mount Emmons. Coals 28 and 29 are nearest in locality to the Mesa mine, are similar in composition to the product of the latter, and illustrate the slight effect of atmospheric agencies upon this class of coal, the samples being from dumps which had been exposed probably between one and three years. Samples 30 and 31 are from a mine one-half to three-quarters of a mile south of those affording 28 and 29. The locality is more remote from the region of greatest metamorphism and considerably nearer the Crested Butte region of coking coal. The gradation from anthracite to bituminous coal, due to position with relation to dynamic influences, is clearly apparent in the intermediate composition of these two samples, especially in the higher percentage of volatile combustible matter and in the tendency to coke.

The coals of the Anthracite range probably merit a higher position in the anthracite class than that indicated in the analyses. The samples of this region were from outcrops, or from exposed faces of coal, which showed considerable fracturing and a consequent high percentage of commingled dirt. The strata are generally undisturbed, and the coals, when opened, may also be found in regular beds.

GEORGE H. ELDRIDGE,
Geologist.

July, 1894.

TABLE A.

Analyses of coals of the Baldwin field, including three from near the Mount Carbon eruptive and one from near the eruptive of Mount Wheatstone.

No. of sample.	Fixed carbon.	Volatile matter.	Water.	Ash.	Sulphur.	Phosphorus.	Specific gravity at temp. C.	Color of ash.	Character of coke.	Remarks.	
1–3	46.95	39.46	8.03	5.54	.97	0.6 (in one sample only)	t. 23.2° 1.331	Light red	Cokes slightly.	Average of three samples of the same seam at different points, where it is 55 3-4 inches, 69 1-4 inches, and 69 3-4 inches thick, respectively.	
6	46 35	40.92	6.28	6.45	.47		t. 21° 1.324	Reddish yellow.	Fair coke.	29 1 2 inches thick, constituting lower bench of seam.	The same seam.
7	49.75	38.06	6.37	5.82	.46		t. 21.6° 1.345	Reddish yellow.	Slightly coherent coke.	28 inches, constituting upper bench of seam.	
8	48.41	39.26	6.39	5.94	.46	0.3	t. 23° 1.337	Red.	Fairly good coke.	57 1-2 inches, or the entire seam.	
5	62.38	30.25	1.34	6.03	.44	0.7	t. 22° 1.325.	Red.	Firm, solid coke.	50 1-2 inches thick.	
9–10	68.31	26.43	1.15	4.10	.60	0.5 (in one sample only)	t. 23° 1.318	Red.	Fair coke.	Average of two samples of the same seam; from dump two years exposed.	
11	82.33	9.96	.81	6.90	1.06		t. 23.8° 1.426	Pinkish gray.	No coke.	From a seam 250 feet beneath that affording 9 and 10; quite near an eruptive mass.	

TABLE B.

Coals of Gibson ridge.

No. of sample.	Fixed carbon.	Volatile matter.	Water.	Ash.	Sulphur.	Phosphorus.	Specific gravity at temp. C.	Color of ash.	Character of coke.	Remarks.	
18	57.73	37.12	1.36	3 79	.49		t. 22.6° 1.288	Light red.	Good	Thickness of seam at point sampled, 69 inches.	Crested Butte mines, No. 3 seam.
19	56.68	38.09	1.47	3.76	.47	.07	t. 21° 1.276	Light red.	Good.	Thickness of seam at point sampled, 66 inches.	
20	51.48	41.07	1.94	5.51	.63	Trace.	t. 21.1° 1.311	Red.	Good.	Thickness of seam at point sampled, 70 inches.	
21	50.49	40.82	2.36	6.83	1.04		t. 22° 1.332	Red.	Good.	Thickness of seam at point sampled, 65 1-2 inches.	
22	54.42	39.51	1.88	4.19	.63		t. 24.8° 1.288	Red.	Good.	Thickness of seam at point sampled, 66 1-2 inches.	
23	52.07	41.74	2.09	4.10	.65	Trace.	t. 26.6° 1.289	Red.	Good.	Thickness of seam at point sampled, 63 inches.	
24	51.97	42 00	1.76	4.27	.75		t. 20° 1.286	Light red.	Good.	Thickness of seam at point sampled, 68 inches.	
avge. of 18–24	53.55	40.05	1.84	4.56	.67						
26	52.34	37.17	3.95	6.54	.42		t. 22.4° 1.328	Red.	Hard, compact coke.	Thickness of seam at point sampled, about 42 inches. No. 3 seam, Crested Butte mines.	
27	51.65	37.86	4 83	5.66	.68		t. 21.2° 1.349	Red.	Fair.	Thickness of seam at point sampled, about 60 inches. From a prospect in Baxter gulch.	

TABLE C.

Coals of Anthracite Mesa, Mount Emmons, and Mount Wheatstone.

No. of sample.	Fixed carbon.	Volatile matter.	Water.	Ash.	Sulphur.	Phosphorus.	Specific gravity at temp. C.	Color of ash.	Character of coke.	Remarks.	
12	85.71	7.92	1.29	5.08	.67		t. 23.4° 1.428	Red.	No coke.	Sample of the entire seam (66 1-2 inches), including chip and block coal, in proportionate amounts.	
13	85.49	7.53	1.36	5.62	.54	0.5	t. 21.8° 1.440	Red.	No coke.	Sample of seam where 55 1-2 inches thick; includes a little chip, but excludes 2 inches dirty coal near top.	
14	86.25	6.68	1.86	5.21	.69	0.8	t. 26.4° 1.465	Red.	No coke.	Sample of 44 1-2 inches solid coal; overlying it is 12 inches chip, here excluded.	
15	72.34	6.59	1.35	19.72	.66		t. 22.2° 1.481	Gray.	No coke.	Sample of 15 inches chip coal at bottom of seam.	Sampled at same point.
16	80.44	7.55	1.30	10.71	.58	.82	t. 22.8° 1.502	Light red.	No coke.	Sample of 10 inches of chip coal at top of seam.	
17	87.46	6.70	1.58	4.26	.58		t. 22.8° 1.455	Red.	No coke.	Sample of 31 3-4 inches of solid coal separating samples 15 and 16.	
28	84.20	8.46	1.22	6.12	.76		t. 22° 1.409	Red.	No coke.	Sample from dump; least weathered coal; exposed 1 to 3 years. No. 2 seam; 36 to 48 inches. Mine closed.	
29	87.24	7.99	1.27	3.50	.62		t. 23.3° 1.409	Red.	No coke.	Sample from dump; least weathered coal; exposed 1 to 3 years. No. 3 seam; 36 to 48 inches. Mine closed.	
30	81.29	14.19	.92	3.60	.52		t. 20.4° 1.359	Light red.	Cokes very slightly.	Sample from side of entry, near entrance to mine; a long exposed surface; represents 8 ins. bottom coal.	
31	81.26	13.40	.81	4.53	.51		t. 20.8° 1.371	Red.	Cokes very slightly.	Sample from same point as No. 30, but from the 36 inches overlying.	

TABLE D.

Coals of the Anthracite range.

No. of sample.	Fixed carbon.	Volatile matter.	Water.	Ash.	Sulphur.	Phosphorus.	Specific gravity at temp. C.	Color of ash.	Character of coke.	Remarks.
25	82.34	4.65	3.95	9.06	.63	0.7	t. 24.4° 1.644	Light red.	No coke.	Thickness, 42–48 inches. The high ash is accidental, the coal being somewhat fractured. Sample is from an old face 40 feet from outcrop.

U.S. GEOLOGICAL SURVEY
J. W. POWELL, DIRECTOR.

TOPOGRAPHY

COLORADO
ANTHRACITE SHEET

Henry Gannett, Chief Geographer.
Triangulation by the Hayden Survey.
Topography by Anton Karl and Laurence Thompson.
Surveyed in 1883 & 1888.

Scale

Contour Interval 100 feet

Edition of Mar. 1894

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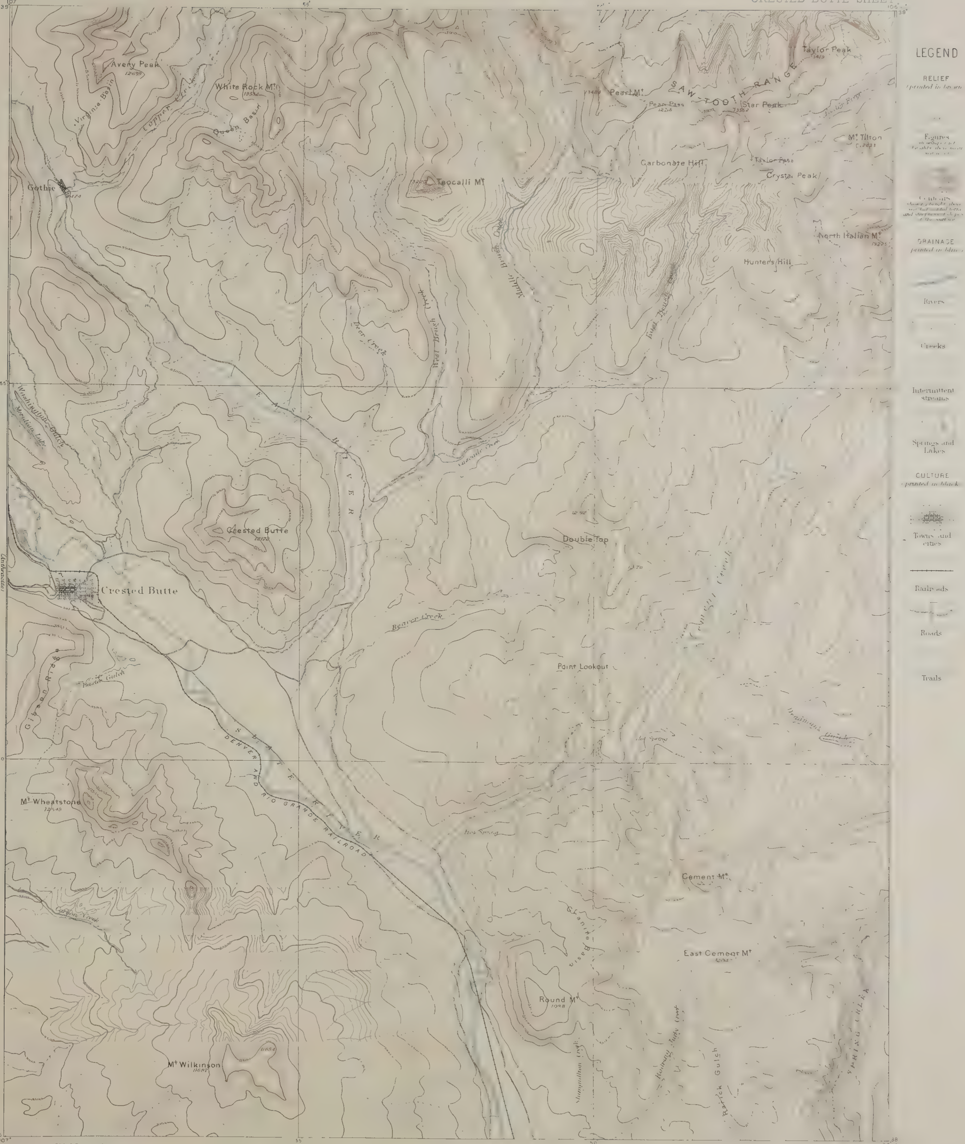
TOPOGRAPHY

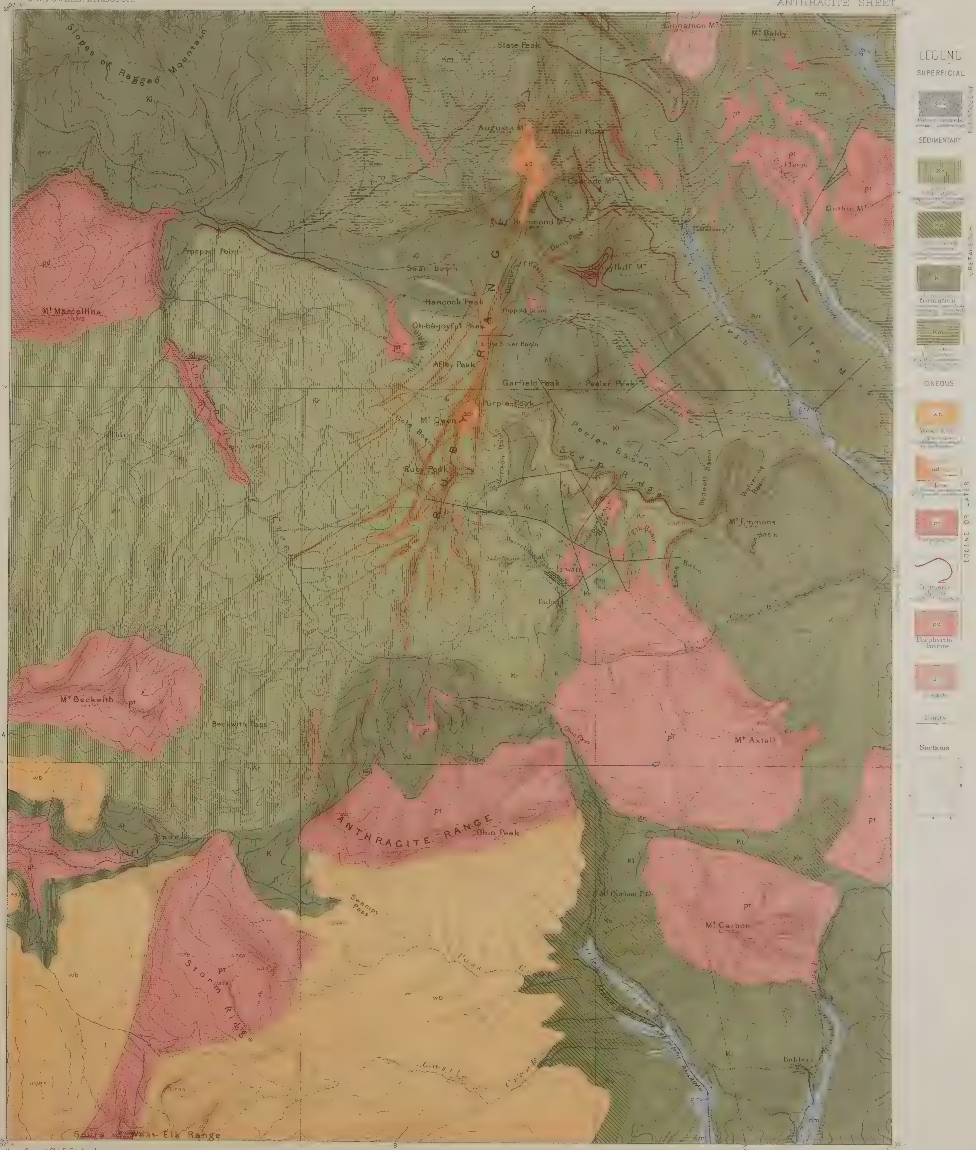
COLORADO
CRESTED BUTTE SHEET



Henry Gannett, Chief Geographer
Triangulation by the Hayden Survey.
Topography by W.H. Leffingwell, and Laurence Thompson
Surveyed in 188-8

Scale 1/62500

Contour Interval 100 feet



Henry Gannett, Chief Geographer.
Triangulation by the Hayden Survey
Topography by Anton Karl and Laurence Thompson
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Scale 1/62500
Contour Interval 100 feet
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F Emmons, Geologist in charge
Geology of Igneous Rocks by Whitman Cross
Geology of Sedimentary Rocks by G.H. Eldridge

Henry Gannett, Chief Geographer
Triangulation by the Hayden Survey.
Topography by W.H. Leffingwell, and Laurence Thompson.
Surveyed in 1883-8

Scale $\frac{1}{62,500}$
0 1 2 3 4 5 Miles
Contour Interval 100 feet
Edition of Mar 1894

S F Emmons, Geologist in charge
Geology of Igneous Rocks by Whitman Cross
Geology of Sedimentary Rocks by G.H. Eldridge
Surveyed in 1884-88

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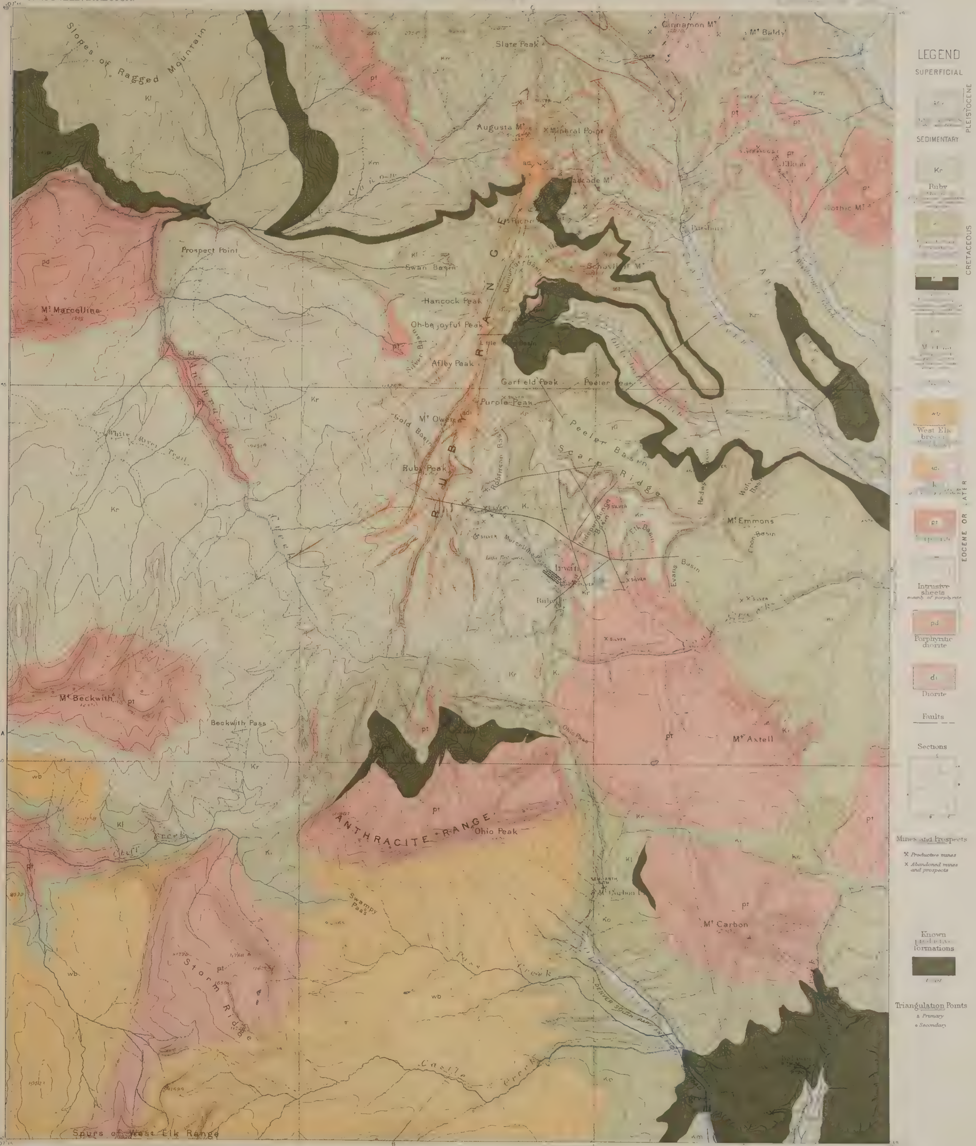
ECONOMIC

COLORADO



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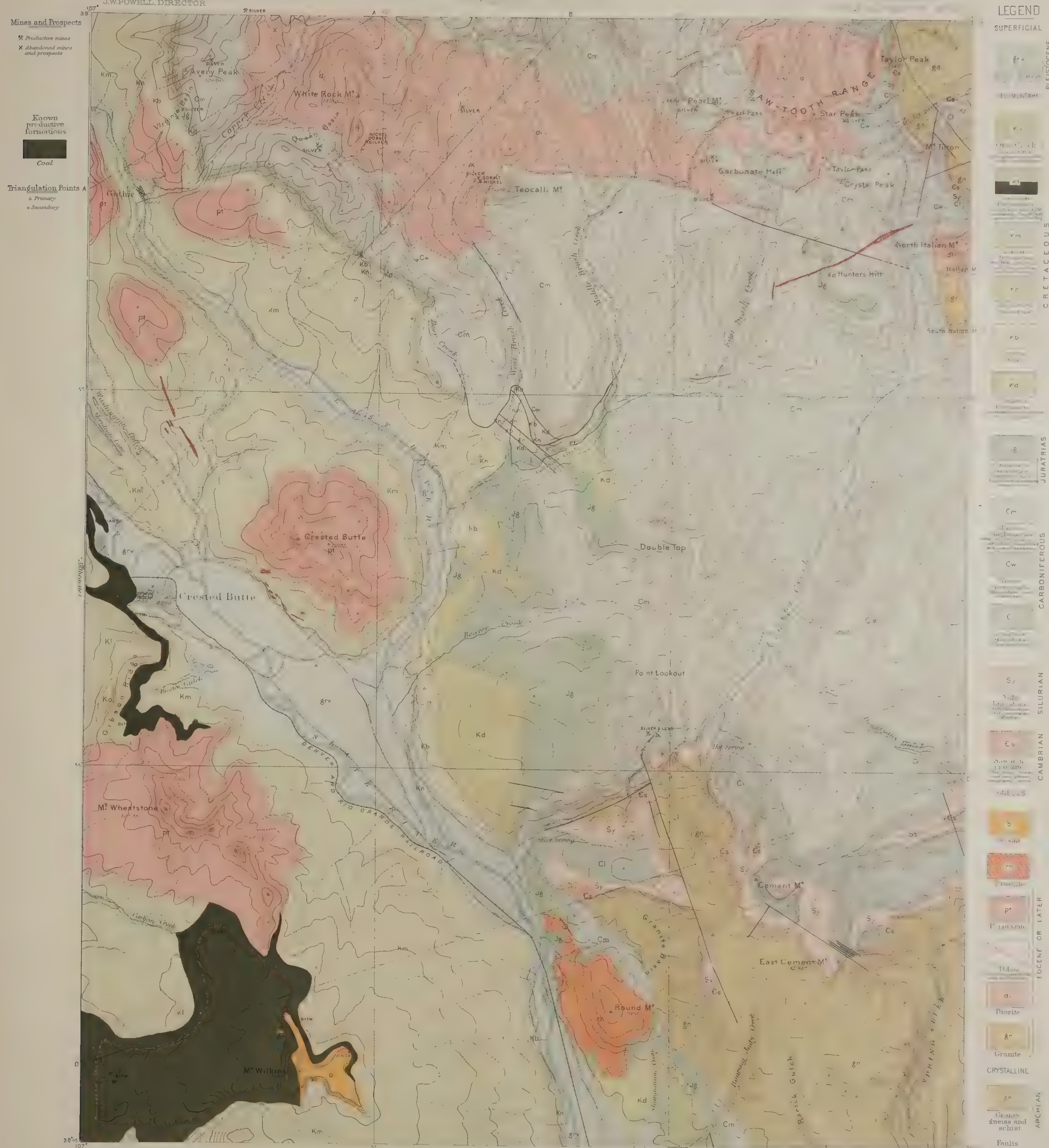

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COLORADO
ANTHRACITE SHEET

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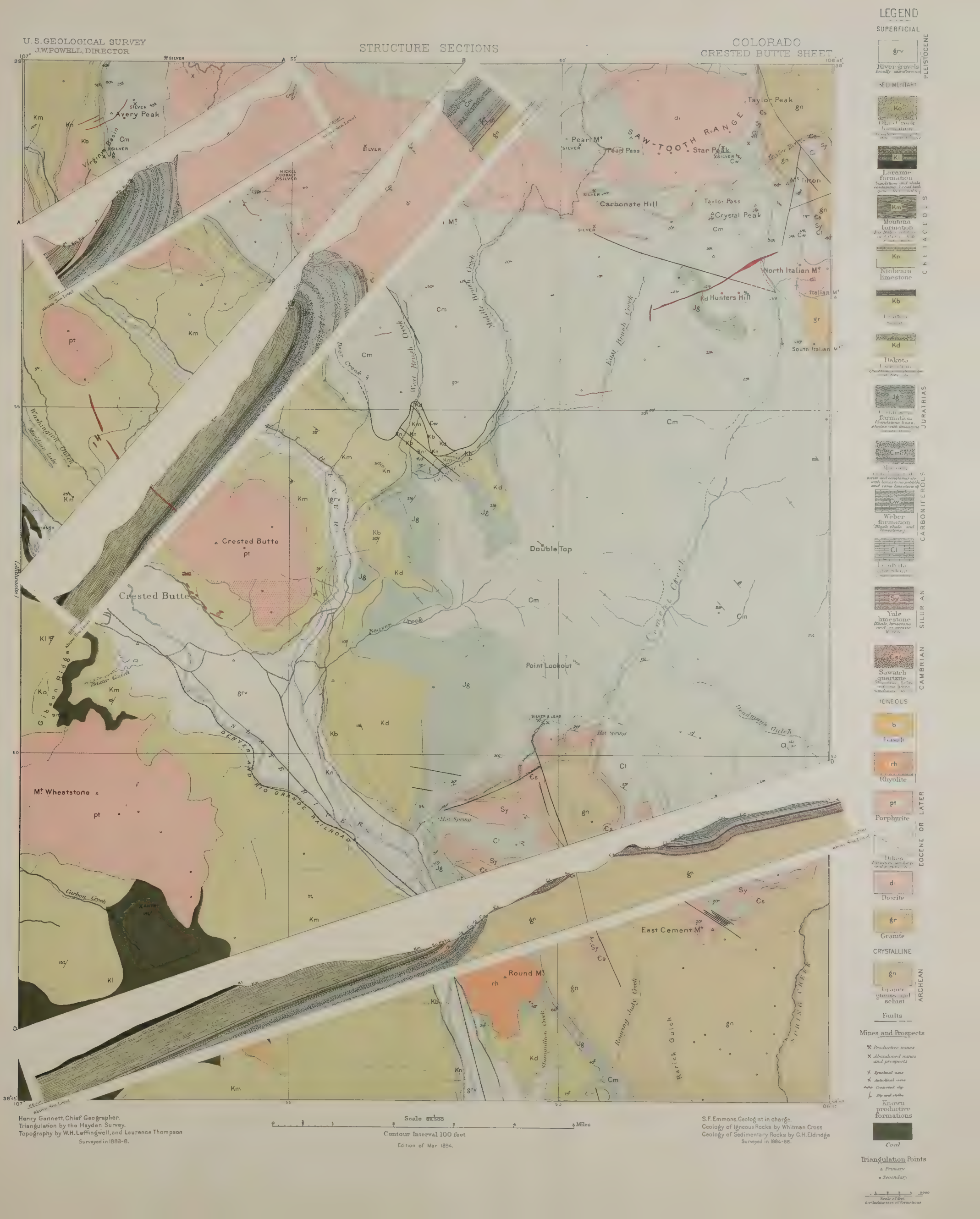
Scale $\frac{1}{62500}$

Contour Interval 100 Feet

Edition of Mar 1894



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STRUCTURE SECTIONS
COLORADO
CRESTED BUTTE SHEET
LEGEND
SUPERFICIAL
River gravels
PLEISTOCENE
SEDIMENTARY
Laramie formation
Montana formation
Niobrara limestone
Dakota
CRETACEOUS
JURATRIAS
Weber formation
CARBONIFEROUS
Yule limestone
SILURIAN
Sawatch quartzite
CAMBRIAN
IGNEOUS
Basalt
Rhyolite
Porphyrite
Dikes
Diorite
Granite
EOCENE OR LATER
CRYSTALLINE
Granite gneiss and schist
ARCHEAN
Faults
Mines and Prospects
Productive mines
Abandoned mines and prospects
Known productive formations
Coal
Triangulation Points
Primary
Secondary
Avery Peak
Virginia Basin
Taylor Peak
SAW-TOOTH RANGE
Pearl Mt
Pearl Pass
Star Peak
Mt Tilton
Carbonate Hill
Taylor Pass
Crystal Peak
North Italian Mt
Hunters Hill
Italian Mt
South Italian Mt
Middle Brush Creek
East Brush Creek
West Brush Creek
Deer Creek
Washington Gulch
Double Top
Crested Butte
Cement Creek
Point Lookout
Coal Creek
Gibson Ridge
Slate River
Hot Spring
Deadmans Gulch
Mt Wheatstone
DENVER AND RIO GRANDE RAILROAD
Carbon Creek
East Cement Mt
Round Mt
Rarick Gulch
Henry Gannett, Chief Geographer.
Triangulation by the Hayden Survey.
Topography by W.H. Leffingwell, and Laurence Thompson
Surveyed in 1883-6.
Contour Interval 100 feet
Edition of Mar 1894.
S.F. Emmons, Geologist in charge.
Geology of Igneous Rocks by Whitman Cross
Geology of Sedimentary Rocks by G.H. Eldridge
Surveyed in 1884-86.

U. S. GEOLOGICAL SURVEY
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COLUMNAR SECTION

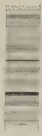
COLORADO
ANTHRACITE – CRESTED BUTTE SHEETS

GENERALIZED SECTION FOR THE ANTHRACITE AND CRESTED BUTTE SHEETS.

SCALE 1000 FEET = 1 INCH.

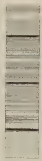
Period.	Formation Name.	Symbol.	Thickness in Feet.	Character of Rocks.
EOCENE OR LATER	West Elk breccia.	wb	3000	The upper part is a bedded breccia. The lower part is a friable tuff with a few thin sandstone beds. The material is mainly dark hornblende-andesite and pyroxene-andesite with some non-eruptive debris in the lower part.
CRETACEOUS	Ruby formation.	Kr	2500	Conglomerate, sandstone, and shale in alternating beds; consisting chiefly of igneous debris—andesites and porphyrites with quartz sand intermingled. The basal conglomerate contains chert and quartz pebbles.
	Ohio formation.	Ko	200	Quartzose sandstone, with pebbles of quartz, vari-colored jasper and clay at the base, forming heavy beds of loose texture and of gray, clouded buff, and red colors.
	Laramie formation.	Kl	2000	Sandstone and shale, with workable coal beds in the lower 400 feet. Quartzose sandstone predominates in the lower half. Somewhat arenaceous shale prevails in the upper half. Plant remains. The coals are anthracite, coking, and dry bituminous.
	Montana formation.	Km	2800	In the upper 300 feet prominent fine grained yellow sandstone corresponding to Fox Hills formation. In the lower 2500 feet leaden gray shale with numerous "lenticular bodies" of limestone, corresponding to the Pierre formation. The entire series is fossiliferous.
	Niobrara formation.	Kn	100–200	The upper two-thirds gray, calcareous shale. The lower one-third light gray limestone.
	Benton formation.	Kb	150–300	Black shale. Thin limestone beds near the top. Ironstone.
	Dakota formation.	Kd	40–300	White quartzite. Conglomerate at the base. Local fire clays.
JURATRIAS	Gunnison formation.	Jg	350–500	The upper two thirds drab, green, yellow, and pink clays, with thin limestone. The base is a heavy white quartzite.
CARBONIFEROUS	Maroon conglomerate.	Cm	2500	Conglomerate and sandstone in heavy beds. The material is chiefly derived from the Archean, but some of the conglomerate contains many limestone pebbles derived from the earlier Carboniferous beds. Occasional thin beds of fossiliferous limestone.
			2000	Quartzose conglomerate, grit, and sandstone with varying amount of pebbles derived from the Carboniferous, which sometimes form the bulk of the deposit. Color, yellowish gray. There are thin, interbedded limestone layers. These and the limestone pebbles are fossiliferous.
	Weber limestone.	Cw	100–550	Dark gray to black shale with thin limestone carrying black chert.
	Leadville limestone.	Cl	400–535	Limestone. The upper third massive, blue and cavernous. The lower two-thirds bedded, gray to brown. Dark cherts.
SILURIAN	Yule limestone.	Sy	350–450	At the top 80 feet of green, pink, and yellow shale and thin limestone. The middle portion massive, gray limestone with white chert.
CAMBRIAN	Sawatch quartzite.	Cs	50–350	The upper two-thirds red quartzite containing glauconite. The lower third quartzite with conglomerate at the base; pebbles, of white quartz.
ARCHEAN		gn		Granite, gneiss, and schist.

Anthracite Range.



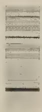
Porphyrite.
Dark shale and sandstone, more or less carbonaceous, in beds, from 1′ to 20′ thick.
Coal, 4″ to 6″.
Dark shale and sandstone, interbedded.
Sandstone, 5′ to 15′.
Coal, 2′ 8″ to 4′.
Shale and sandstone, interbedded.
Sandstone.
Shale, carbonaceous, with thin sandstone layers; 30′.
Sandstone, slightly carbonaceous; 10′ to 30′.
Base of the Laramie.

Coal Gulch, opposite Baldwin.



Sandstone and shale.
Coal, 3′.
Arenaceous shale and sandstone 100′.
Coal, 4′ 6″.
Arenaceous shale and clayey sandstone, interbedded; 110′.
Coal streak.
Sandstone and shale, 40′.
Coal, 4′ 6″.
Sandstone, light gray, quartzose, with thin layers of shale; 50′ to 80′.
Base of the Laramie.

Baxter Gulch.

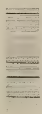


Coal streak.
Shale and sandstone, 60′
Coal streak.
Sandstone and shale, interbedded, 150′
Coal, 5′.
Sandstone, white, 50′–80′.
Base of the Laramie.

Crested Butte.

Coal, 3′ 6″.
Sandstone and shale, interbedded, 140′.
Coal, 5′ 6″.
Sandstone and shale, 40′.
Coal, 5′.
Sandstone, white, 50′–80′.
Base of the Laramie.

Anthracite Mesa.



Coal thin.
Shale and sandstone interbedded, 125′
Coal, 3′ 6″.
Shale and sandstone, 40′.
Coal, 4′ 6″.
Sandstone and shale, 60′.
Coal, thin.
Sandstone, white, 50′–80′
Base of the Laramie.